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WALNUT APHIDES IN CALIFORNIA.

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INTRODUCTION.

The study of walnut aphides dealt with in the following pages was begun early in the year 1911 and continued until the summer of 1913. The observations were at first made at San Jose, Cal., but after September, 1912, the work was done chiefly at Walnut Creek, Cal. Practically all the life-history observations were made at the former locality, and much of the control work was done at Walnut Creek. The habits of the aphides do not vary materially throughout California. It was at first the writer's intention to confine his studies to the European walnut aphis (*Chromaphis juglandicola* Kalt.), as this species alone infests walnuts of commercial value grown in California, but latterly two native species of Aphididæ were found to be pests on native walnuts much used for stock on which to graft the European or Persian nut, and thus the studies were extended so as to include all three species. The two native aphides above mentioned are *Monellia caryæ* Monell, the American walnut aphis, which affects the eastern black walnut (*Juglans nigra*) and *Monellia caryella* Fitch, the little hickory aphis,[1] which affects the California black walnut (*Juglans californica*). Both of these species infest the Royal Hybrid walnut (a cross between the eastern black walnut and the California black walnut), while the Paradox Hybrid walnut (a cross between the European walnut and the California black walnut) is attacked by the European walnut aphis and to a lesser extent by the little hickory aphis. Both of these hybrids are rapid growers, and a certain percentage of the seedlings obtained from the crossings makes good stock on which to graft the commercial varieties of nuts. The great majority of European nuts and their varieties are grown in California

[1] This is the name Fitch gave to species which he found on hickory, and it seems best to retain it, although rather an unfortunate title in so far as California is concerned, as the only wild member of the Juglandaceæ in that State is *Juglans californica*.

on roots of either the California black walnut straight or on roots of one or the other of these two hybrids. When a graft has been made and both stock and scion are putting out leaves simultaneously, more than one species of aphis will usually occur on the same tree. In such a case the two species feed on their own particular host, but the migrant forms of either may be found resting on foliage of the opposite host. The Paradox and Royal hybrids are used in various parts of California as shade trees and will furnish a fine grade of wood, which will take on a high polish.

THE EUROPEAN WALNUT APHIS (Chromaphis juglandicola Kaltenbach).

Lachnus juglandicola Kaltenbach, Monographie der Familien der Pflanzenlause, Aachen, 1843.

Callipterus juglandicola Koch, Die Pflanzenläuse Aphiden, Nürnberg, p. 224, 1857.

Callipterus juglandicola Passerini, Gli Afidi, Parma, 1860.

Callipterus juglandis Walker, The Zoologist, ser. 2, v. 5, p. 2000, Feb., 1870.

Pterocallis juglandicola Buckton, Monograph of the British Aphides, v. 3, London, 1881, p. 32–34.

Callipterus juglandicola Schouteden, Mem. Soc. Ent. Belg., v. 12, p. 209–210.

Chromaphis juglandicola Essig, Mo. Bul. Cal. State Com. Hort., v. 1, no. 5, p. 190–194, figs. 72–73, April, 1912.

In 1870 Walker erected the genus *Chromaphis* and designated *Callipterus juglandicola* Kaltenbach as the type species. Reference to this is made by H. F. Wilson in his paper "A Key to the Genera and Notes on the Synonymy of the Tribe Callipterini, Family Aphididae," Canad. Ent., v. 42, no. 8, p. 253–259, Aug., 1910.

HISTORY OF THE SPECIES.

The species was described originally by J. H. Kaltenbach in his "Monographie der Familien der Pflanzenläuse" as *Lachnus juglandicola*. A somewhat free translation of this description is as follows:

Wingless: Pale yellow, egg-shaped, flat, square, incised, and armed with glandular hairs on the margins; legs whitish-yellow, a black spot on the apex of the hind femora. Length, $\frac{1}{2}''$.

Winged: Yellow; eyes red; antennæ whitish, with black rings; cornicles yellow, hardly noticeable; tail lacking.

This tree louse occurs sporadically in June and July in numbers under the leaves of the walnut tree (*Juglans regia*).

Wingless: Antennæ shorter than the head and thorax combined, not markedly jointed, whitish-yellow. Apex of antennæ black, of third joint ringed black. Eyes light red; beak short, scarcely reaching to the first coxæ. On the dorsum occur two longitudinal rows of black spots, which are absent on younger individuals. Cornicles and tail lacking. Legs hyaline whitish-yellow; a black spot is found on the upper side of the hind femora at their apices.

Winged: Antennæ noticeably shorter than the body, pale, the four major joints black at their apices; third joint distally enlarged; sixth joint with a gradually tapering thin apex. The body is yellow; in many cases the black dorsal spots of the abdomen are absent; in other cases but two to six are present; cornicles scarcely per-

ceptible, yellow; tail not present. Legs pale; the spots on the apex of the hind femora are larger than those of the wingless. In well-colored examples such spots occur on the middle femora and those on the hind femora are enlarged into a ring. The wings are transparent; the stigma yellow, cubitus and the two inner veins brown and markedly stouter at the base, then gradually becoming finer and paler; veins of lower wing and wing margin pale yellow; stigmatic or fourth vein very fine and strongly curved.

There is no doubt that Kaltenbach's species is the same that occurs commonly all over California on the European walnut. The black femoral spot, together with the antennæ as described, establishes its identity. Kaltenbach's wingless form appears to be the oviparous female in her penultimate molt, for the true apterous viviparous female—a common form in the majority of plant lice—does not exist, or, if it does, is extremely rare, the author in two years of close observation having failed to observe it. Buckton (1872) [1] gives a description of the apterous viviparous form, but he also seems to have had before him the immature oviparous form.

The insect probably occurs wherever the European walnut is grown. It has been reported from all over Europe, as well as from the States of Colorado (Gillette, 1910), Oregon (Wilson and Lovett, 1911–12), and California (Essig, 1909).

GENERAL DESCRIPTION; CHARACTER AND EXTENT OF INJURY.

This aphidid is a small, lemon-yellow insect, about one-sixteenth of an inch in length. It occurs sporadically on the underside of the leaves and on the young fruit of the European walnut (*Juglans regia*) and its cultivated forms and hybrids. It appears on the upper surface of the leaf only at times of very severe infestation. It is to be found from late February or early March until December, persisting as long as the leaves remain on the tree, but is present in greatest numbers during the months of July and August. As many as 200 individuals may occur on a single large leaflet if infestation be severe, while the author has observed over 30 aphides on a single young nut. Nuts badly infested while young never attain their normal size. Many of them mature half-sized, covered on the upper surface with the black sooty fungus which thrives on the sticky exudations of the aphides. Attacks on the tree year by year also materially reduce its vitality, since the aphides will be present in the spring even before the leaves have opened and will remain until these drop.

Plate I, figure 1, shows the difference in size between infested and uninfested nuts of one variety of European walnut, while Plate I, figure 2, demonstrates the appearance of the sooty fungus on a walnut leaf.

[1] Dates in parentheses refer to the Bibliography, p. 47.

LIFE HISTORY AND TECHNICAL DESCRIPTIONS.

The Viviparous or Asexual Forms.

When the young stem-mother is ready to emerge in the spring she causes the shell of the winter egg to burst with a longitudinal slit on the dorsal surface from the micropylar end. (See fig. 1.) Egress is performed head first, and antennæ and legs are requisitioned by the young larva in worming its way out of the shell. While the process of emerging, which occupies half an hour or more, is taking place, the aphis assumes an erect position at right angles to the long axis of the egg. After the exit of the young the eggshell has a large triangular hole at the micropylar end.

As soon as the buds begin to swell in early spring these stem-mothers hatch and continue hatching until the leaves have fully opened out, at which time all will have issued from the egg. The earliest plant-lice to emerge may be seen wandering over the bare twigs and buds, apparently feeding a little upon the scales protecting the unopened buds, but not showing much growth until the buds have opened and can afford nourishment.

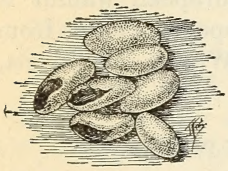


Fig. 1.—*Chromaphis juglandicola:* Group of eggs, three lowest hatched. Twenty times natural size. (Original.)

Undoubtedly many of the aphides that hatch early die of ill nourishment, and some of these do not attain their full development for six or seven weeks, while those hatching later and finding tender food in abundance become full grown at the end of five weeks. Certain it is that on a particular tree the stem-mothers all became winged almost simultaneously. On trees which leaf early the stem-mothers will begin emerging from the egg as early as February 15, but on the Franquette and such late varieties no aphides will be found until in April. Immediately after hatching the lice seek the buds or young leaves. In the former case the aphides crawl in between the scales, but on the leaves they appear on the lower or exposed side, notwithstanding the fact that much better protection is afforded by the upper, as yet unfolded, surface which at that time is almost entirely hidden from view. Possibly the sticky character of the upper surface of the leaves repels them. Table I indicates the life cycle of four stem-mothers which hatched after the buds had opened.

Table I.—*Period of development of the stem-mother of Chromaphis juglandicola, San Jose, Cal., 1912.*

No. of individual.	Date of hatching.	Date of acquiring wings.	Period from hatching to maturity.
			Days.
1	Mar. 24	Apr. 28	35
2	24	28	35
3	24	28	35
4	24	29	36
Average period			35.25

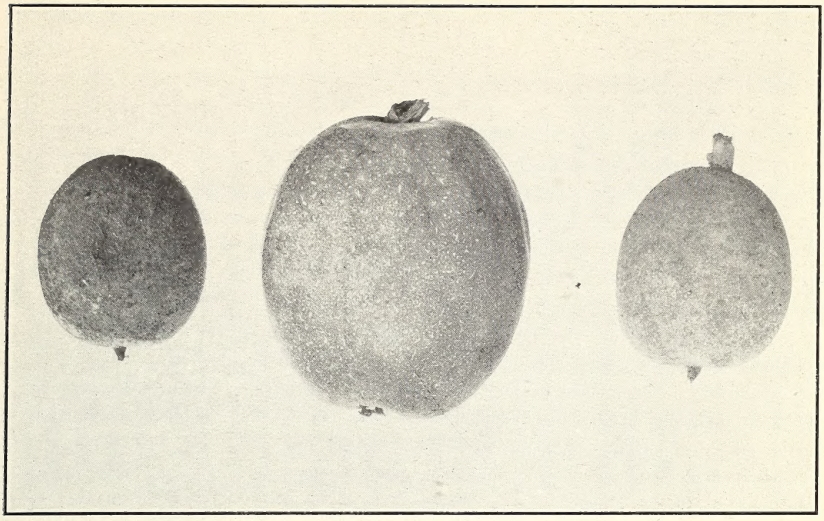


FIG. 1.—THREE MATURED NUTS OF EUROPEAN WALNUT SEEDLING.

[Middle nut natural size, other two undersized from attack by aphides.]

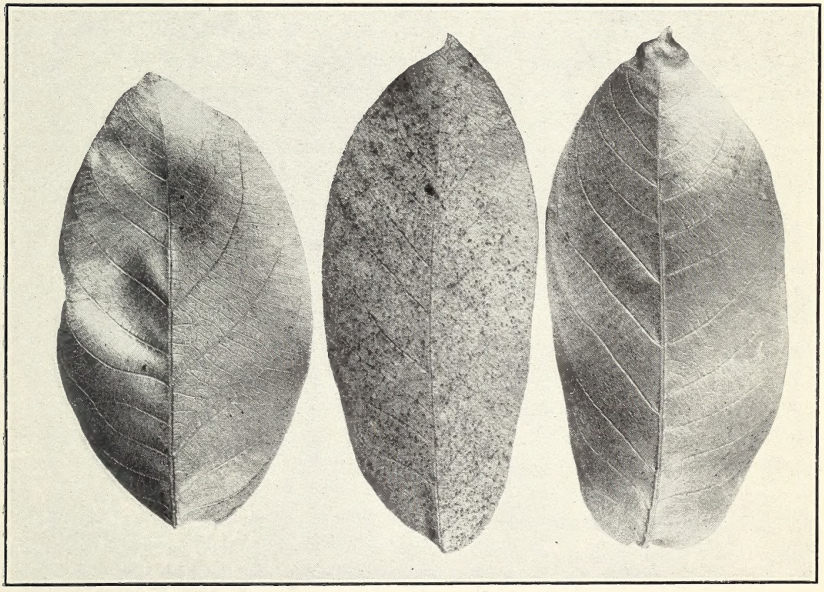


FIG. 2.—UPPER SIDE OF THREE LEAFLETS OF EUROPEAN WALNUT SEEDLING.

[The central leaflet shows growth of fungus thriving upon the exudation of aphides above. Two-thirds natural size.]

THE STEM-MOTHER; NEWLY HATCHED YOUNG (FIG. 2).

Oval, lemon yellow. Eyes red, of moderate size. Antennæ 3-jointed, not quite reaching to base of second coxæ; joint III nearly three times as long as joints I and II together. Legs comparatively long, entirely pale. Body covered with capitate hairs. Cornicles very small, pale whitish-yellow, hardly raised above the surface of the body. Cauda small, pale, bluntly conical. Beak entirely pale, reaching second coxæ. Black knee spots characteristic of this species absent. Measurements: Length of body, 0.72 mm.; width, 0.30 mm.; antenna, joint I, 0.04 mm.; joint II, 0.035 mm.; joint III, 0.145 mm. Almost immediately after birth the legs and antennæ turn dusky gray and the dark abdominal spots appear. In this respect the young of the stem-mothers differ from those of all other generations, for the appendages of the young aphides of subsequent broods never turn entirely dusky nor do the abdominal spots appear so early.

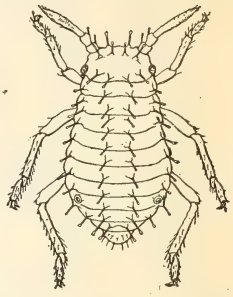


FIG. 2.—*Chromaphis juglandicola:* Stem-mother, newly hatched. (Original.)

THE STEM-MOTHER; 4 DAYS OLD.

Yellowish-green, flatly oval, closely appressed to the surface of the leaflet or bud scale. Antennæ and legs dusky gray. Eyes circular, red, small. Head, thorax, two proximal antennal joints, and abdomen bearing capitate hairs which arise (those of the antennæ excepted) from small tubercules situated in the middle of a small, circular, dusky area. Antennæ 3-jointed, the distal joint the largest. Cornicles very small, erect. Cauda almost as long as the hind tarsus, its apex blunt. Cornicles and cauda concolorous with the abdomen. Beak very pale, reaching second coxæ, its extreme apex brown. Underside of the head very pale yellow; of the abdomen greenish-yellow.

THE STEM-MOTHER; AFTER FIRST MOLT AND JUST PREVIOUS TO SECOND MOLT.

Pale lemon-yellow or yellowish green, flatly oval, closely appressed to the plant surface, occurring on the underside of the expanding leaves, between the ribs. Antennæ and legs very pale yellow, almost hyaline. Antennæ short, reaching slightly beyond the posterior margin of the prothorax, 3-jointed, with a rudimentary suture on the distal half of joint III. This joint is about three times as long as the two proximal joints together. Eyes crimson, not fully developed. Legs entirely pale, without any trace of dark knee spots. Thorax and segments 1 to 6 of the abdomen with two longitudinal rows of black or brown spots, on each of which occurs a small pale tubercle bearing two capitate hairs, one larger than the other. On the thoracic segments and on abdominal segments 1 to 7 occur two rows of pale lateral tubercles, each of which bears three capitate hairs. The frontal margin of the head bears six such hairs on tubercles. Antennal joints I and II with a capitate hair on their inner margins near the middle, and joint III with one such hair on the inner margin near the base. The eighth abdominal segment bears a dorsal fringe of six capitate hairs, those on either end being smaller than the four inner ones. Cornicles situated on segment 6, as broad as long, erect, concolorous with the abdomen. Cauda without armature, bluntly conical, almost hyaline, about as long as the hind tarsus. Beak barely reaching second coxæ, pale yellow, the extreme tip brown. Measurements: Length of body, 1.55 mm.; width, 0.775 mm.; antenna, joint I, 0.053 mm.; joint II, 0.048 mm.; joint III, 0.304 mm.

Described from specimens collected at San Jose, Cal., March 28, 1912.

After the second molt the spines on the dorsum of the body disappear. (See fig. 3.)

The pupal and imaginal stages of the stem-mother show no apparent difference in respect to size, color, or structure from those of the later viviparous generations, and thus one description of these forms will suffice for all the winged viviparous generations.

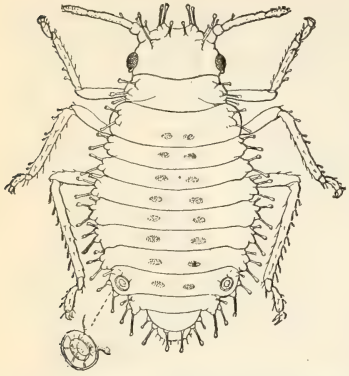


FIG. 3.—*Chromaphis juglandicola:* Larva of stem-mother after second molt. (Original.)

THE PUPA OF THE WINGED VIVIPAROUS FEMALE (FIG. 4).

General color pale lemon-yellow. Eyes red, fully formed. Antennæ reaching a little beyond the base of the wing-pads, pale, joint III the longest, joints IV and V subequal. Ocelli present. Anterior margin of the head bearing six capitate spines. Thoracic segments pale yellow. Wing-pads pale yellow, closely appressed to the sides of the body. Legs pale yellow, with the dark knee spot on the hind femora only; tarsi dusky. Abdomen oval, pale lemon-yellow, with a varying number of dark spots on the dorsum, which spots are always present on segment 5 but often lacking on the other segments. Head, thorax, and abdomen furnished with lateral rows of capitate hairs which stand on small pale tubercles. Cornicles small, as wide as long, slightly constricted in the middle, situated on the sixth abdominal segment. Cauda short, about as long as the cornicles, bluntly rounded at the apex. Cornicles and cauda concolorous with the body. Beak short, pale, stout, reaching to the first pair of coxæ. The pupa has the legs relatively a little shorter than those of the adult and is thus more closely appressed to the leaf surface. The body is quite flat. Measurements: Length of body, 1.87 mm. (average); width, 0.85 mm. (average maximum); antenna, joint I, 0.050 mm.; joint II, 0.042 mm.; joint III, 0.183 mm.; joint IV, 0.081 mm.; joint V, 0.076 mm.; joint VI, 0.065 mm.; filament, 0.034 mm. Cornicles, 0.04 mm.

The stem-mothers pass through the pupal molt about one week before the final molt takes place, and after the latter they acquire their full development as winged adults. In the latter generations the pupal instar occupies from three to six days.

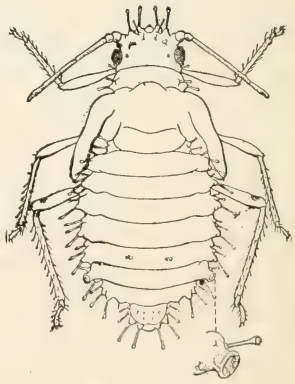


FIG. 4.—*Chromaphis juglandicola:* Pupa of winged viviparous female. (Original.)

THE WINGED VIVIPAROUS FEMALE (FIG. 5).

General color pale lemon-yellow; many individuals are darker yellow, yellowish-brown, or salmon-pink. Antennæ on very small frontal tubercles, about one-half the length of the body, yellow, with the inner lateral margins of the first two joints dusky; articulations of joints III to VI and the whole filament dusky to black. Eyes red. Ocelli present. Prothorax yellow. Thoracic lobes and scutellum light brown, sometimes greenish-yellow, pale yellow in newly-molted individuals. Wings of medium

size; subcosta and wing insertions pale yellow; stigma pale gray, with a darker area at the confluence of the third discoidal vein, and another such though smaller area at the apex; veins rather heavy, dark brown, all three discoidals arising from the subcosta and thickened at their bases; second branch of third discoidal nearer the wing apex than the first fork; third discoidal describing a regular gentle curve for its entire length; stigmatic vein entire, the depth of its curve varying in different examples, generally reaching the wing margin midway between the apex of the stigma and the the end of the third discoidal (often it touches the margin considerably nearer the stigma, but rarely nearer the third discoidal). Legs rather short, but a little longer than those of the pupa; front pair yellow with the tarsi and apical third of the tibiæ dusky

FIG. 5.—*Chromaphis juglandicola:* Winged viviparous female (appendages of left side removed). *a*, Left antenna; *b*, right cornicle; *c*, front tarsus. (Original.)

gray and the knee spot rarely present (gray when present); middle pair yellow, with an indefinite gray spot on the upper side of the femur above the knee and with the tarsi dusky gray; hind pair yellow, with a coal-black spot (sometimes produced into an annulation) on the upper side of the femur above the knee joint and with the tarsi dusky gray as in the other pairs. The knee spots are always present on the hind femora, while they occur in about 80 per cent of individuals on the middle femora. In 35 individuals examined throughout the year all had the spots on the hind femora, 28 had spots on the middle femora, and only 1 had spots on the fore femora. Abdomen pale lemon-yellow, widest at segment 3, considerably wider than the thorax, generally bearing two oval brown spots on segment 5 and more rarely with two similar but smaller spots on segment 4; occasionally immaculate. These spots are sometimes grayish, varying in intensity, and appear to be the pupal markings retained in the adult form.

Cornicles (fig. 5, *b*) pale yellow, constricted in the middle, barely as long as broad. Abdominal segments 3 to 6 inclusive bearing pale lateral tubercles. Body without hairs. Cauda very pale, globular, about as long as the cornicles. Beak pale yellow, the extreme tip black, reaching a little beyond the first coxæ. Sternum pale brown. Measurements: Length of body, 1.62–2.55 mm., average 2.08 mm.; width of body at segment 3 of abdomen, 0.71–1.06 mm., average 0.88 mm.; wing expanse, 4.42–5.21 mm., average 4.77 mm.; antenna, joint I, 0.046–0.067 mm., average 0.055 mm.; joint II, 0.039–0.055 mm., average 0.043 mm.; joint III, 0.267–0.408 mm., average 0.337 mm.; joint IV, 0.153–0.233 mm., average 0.196.mm.; joint V, 0.133–0.191 mm., average 0.162 mm.; joint VI, 0.079–0.094 mm., average 0.083 mm.; antennal filament, 0.038–0.043 mm., average 0.040 mm.; total length of antenna, 0.775–1.060 mm., average 0.916 mm.; cornicles, 0.05 mm.; cauda, 0.056 mm.

There are from 6 to 8 transverse oval sensoria on antennal joint III, 1 terminal sensorium on joint V, and three terminal ones on joint VI. Buckton's measurements (Buckton, 1872) seem to have been taken from small examples for, with the exception of those of the antennal joints, his measurements are all smaller than the average found by the writer. It may be that California examples are larger than the European.

Within a few hours after the last molt the wings harden and the chitin stiffens. The stem-mothers then begin to deposit the young that have been visible as pseudova for a week or longer inside their bodies. In the life-history experiments the greatest number of young produced by one viviparous female was 44. These were extruded from the body in 20 days, 30 in the first half and 14 in the last half of that period. Several adults under observation deposited 11 or 12 young within 12 hours after reaching maturity, and no more after that, dying with many unborn pseudova in their bodies. In the field the aphides deposit all their young on one leaf or on several leaves near one another. The average number of young deposited by a single adult ranges between 25 and 35. This seems to be about the same as in other closely related Callipterini, but is a much smaller number than that occurring in members of other tribes of Aphididæ. The aphides of the fall viviparous generation produce fewer young, those which develop in November depositing only 6 or 8. As many as 30 oval unborn aphides may be seen in the body of one recently molted female. These embryos vary in size, only those to be deposited immediately being fully grown. Each is inclosed in a very thin hyaline sac in which they are contained at birth.

The newly deposited young of the second and subsequent generations, both viviparous and oviparous, differ from the infant stem-mothers in that they are entirely pale yellow (rarely suffused with a faint pink) and remain thus until the first molt, while the young stem-mothers have dusky appendages and abdominal spots. The young deposited by the stem-mothers pass through their first molt in from three to six days. After this molt there appear brown or black dorsal spots in the majority of the individuals, and these markings persist through the succeeding molts. A small percentage

of examples remain immaculate throughout development. The "lice" of the second generation develop more quickly than the stem-mothers or first generation, owing to greater abundance of food supply and to the higher temperature existing at that later period. In 1911 second-generation young were deposited in the field on early varieties of walnuts a little before April 23, while in the following year these were deposited as early as April 6. This is to be expected, since in 1912 the trees came out in leaf two weeks earlier than in the previous year. Table II shows the life cycle of 41 individuals of the second generation at San Jose, Cal., in 1911.

TABLE II.—*Life cycle of the second generation of Chromaphis juglandicola, San Jose, Cal., 1911.*

No. of individual.	Date of—		Life cycle.	No. of individual.	Date of—		Life cycle.
	Deposition.	Acquiring wings.			Deposition.	Acquiring wings.	
			Days.				*Days.*
1	Apr. 23	May 12	19	22	May 2	May 22	20
2	23	12	19	23	2	22	20
3	23	14	21	24	3	22	19
4	23	16	23	25	3	22	19
5	23	18	25	26	3	22	19
6	24	18	24	27	3	22	19
7	24	18	24	28	3	22	19
8	24	18	24	29	4	23	19
9	24	18	24	30	4	23	19
10	24	18	24	31	5	25	20
11	25	20	25	32	5	25	20
12	26	21	25	33	5	25	20
13	May 1	21	20	34	6	26	20
14	1	21	20	35	6	26	20
15	1	21	20	36	6	27	21
16	1	21	20	37	6	27	21
17	1	21	20	38	6	27	21
18	2	21	19	39	7	27	20
19	2	21	19	40	8	28	20
20	2	22	20	41	9	27	18
21	2	22	20				

Life cycle:	Days.
Maximum	25
Minimum	18
Average	20.7

The aphides of the third generation appear on the earliest varieties of walnuts about the middle of May, but on the late varieties such as the Franquette this brood appears as much as a month later. The individuals of this generation are on the average slightly larger than those of other generations. In a large series of adult viviparous females taken throughout the year of 1911 the largest example was of the third generation. Its body was 2.55 mm. in length and 1.06 mm. in width, and both of its antennæ measured 1.06 mm., or 0.02 mm. in excess of the next longest antenna in the series. Table III indicates the life cycle of 97 individuals of the third generation.

TABLE III.—*Life cycle of the third generation of Chromaphis juglandicola, San Jose, Cal., 1911.*

No. of individual.	Date of—		Life cycle.	No. of individual.	Date of—		Life cycle.
	Deposition.	Acquiring wings.			Deposition.	Acquiring wings.	
			Days.				*Days.*
1	May 19	June 4	16	50	May 19	June 7	19
2	19	4	16	51	19	7	19
3	19	4	16	52	19	7	19
4	19	4	16	53	19	7	19
5	19	5	17	54	19	7	19
6	19	5	17	55	19	7	19
7	19	5	17	56	19	7	19
8	19	5	17	57	19	8	20
9	19	5	17	58	19	8	20
10	19	5	17	59	19	8	20
11	19	5	17	60	19	8	20
12	19	5	17	61	19	8	20
13	19	5	17	62	19	8	20
14	19	5	17	63	19	8	20
15	19	5	17	64	19	8	20
16	19	5	17	65	19	9	21
17	19	5	17	66	19	9	21
18	19	6	18	67	22	10	19
19	19	6	18	68	22	11	20
20	19	6	18	69	22	11	20
21	19	6	18	70	22	11	20
22	19	6	18	71	22	11	20
23	19	6	18	72	22	11	20
24	19	6	18	73	22	11	20
25	19	6	18	74	22	11	20
26	19	6	18	75	22	11	20
27	19	6	18	76	22	11	20
28	19	6	18	77	22	11	20
29	19	6	18	78	22	11	20
30	19	6	18	79	22	11	20
31	19	6	18	80	22	11	20
32	19	6	18	81	22	11	20
33	19	6	18	82	22	11	20
34	19	6	18	83	22	11	20
35	19	6	18	84	22	12	21
36	19	6	18	85	22	12	21
37	19	6	18	86	22	12	21
38	19	6	18	87	22	12	21
39	19	6	18	88	22	12	21
40	19	6	18	89	22	12	21
41	19	6	18	90	22	13	22
42	19	6	18	91	22	13	22
43	19	7	19	92	22	13	22
44	19	7	19	93	22	14	23
45	19	7	19	94	22	14	23
46	19	7	19	95	22	14	23
47	19	7	19	96	22	15	24
48	19	7	19	97	22	15	24
49	19	7	19				

Life cycle:	Days.
Maximum	24
Minimum	16
Average	19.1

Generations IV to VIII inclusive occupy roughly 16 days apiece for development, and this period is the average life cycle during the summer months. Some aphides will develop in 14 days and others in 19 or 20. Table IV gives the life-cycle records of these five generations and also that of the ninth. The records in some instances are small, but the fact that in the first five of these generations there is practically no difference in the duration of the life cycle was corroborated by a larger series of experiments during the summer months with individuals of which the respective generations were unknown.

TABLE IV.—*Life cycle of the summer generations of Chromaphis juglandicola, San Jose, Cal., 1911.*

Generation No.	No. individual.	Date of—		Life cycle.	Form of individual.
		Deposition.	Reaching adult state.		
				Days.	
	1	June 8	June 28	20	Viviparous.
	2	16	July 1	15	Do.
	3	16	1	15	Do.
IV	4	16	1	15	Do.
	5	16	2	16	Do.
	6	16	2	16	Do.
	7	16	2	16	Do.
	1	July 1	15	14	Do.
V	2	1	15	14	Do.
	3	1	17	16	Do.
	4	1	18	17	Do.
	1	15	31	16	Do.
	2	15	31	16	Do.
	3	15	31	16	Do.
	4	15	31	16	Do.
	5	15	31	16	Do.
	6	15	31	16	Do.
	7	15	31	16	Do.
	8	16	Aug. 1	16	Do.
	9	16	1	16	Do.
	10	16	1	16	Do.
VI	11	16	2	17	Do.
	12	16	2	17	Do.
	13	16	2	17	Do.
	14	16	2	17	Do.
	15	17	2	16	Do.
	16	17	2	16	Do.
	17	17	2	16	Do.
	18	17	3	17	Do.
	19	17	4	18	Do.
	20	18	5	18	Do.
	21	18	6	19	Do.
	22	18	6	19	Do.
	1	Aug. 2	17	15	Do.
	2	2	17	15	Do.
VII	3	2	17	15	Do.
	4	2	19	17	Do.
	5	3	20	17	Do.
	6	3	20	17	Do.
	7	3	20	17	Do.
	1	18	Sept. 1	14	Do.
	2	19	2	14	Oviparous.
	3	19	2	14	Do.
	4	19	3	15	Do.
	5	19	3	15	Do.
	6	19	3	15	Do.
	7	19	3	15	Do.
	8	19	3	15	Do.
VIII	9	19	3	15	Do.
	10	20	4	15	Do.
	11	20	4	15	Do.
	12	20	4	15	Do.
	13	20	6	17	Viviparous.
	14	20	6	17	Oviparous.
	15	20	6	17	Do.
	16	20	7	18	Viviparous.
	1	Sept. 5	30	25	Oviparous.
	2	5	Oct. 1	26	Do.
	3	5	6	31	Viviparous.
	4	5	6	31	Do.
	5	5	8	33	Do.
	6	5	8	33	Do.
	7	7	9	32	Do.
IX	8	7	11	34	Do.
	9	7	13	36	Do.
	10	7	14	37	Do.
	11	7	14	37	Do.
	12	8	12	34	Do.
	13	8	17	39	Do.
	14	8	17	39	Do.

An inspection of Table IV shows that the length of the life cycle of Generations IV to VII was almost the same. This is to be expected, since in 1911 the months of June, July, and August had almost identical temperatures both day and night. It will also be observed that there was a very noticeable difference between the life-cycle periods of Generations VIII and IX, 16 individuals of the eighth generation averaging 15.4 days and 14 individuals of the ninth generation averaging 33.4 days. The ninth generation thus required for development a period over twice as long as that required by the preceding generation, developing almost as slowly as the stem mother generation (see Table I). Yet the temperature during the daytime influencing the ninth generation differed but little from those which obtained during the development of the eighth. The probable causes of the slow development of the ninth generation lice is to be found in the colder night temperatures to which they were subjected and in the fact that the leaves at this time are becoming less vigorous and consequently afford poorer nourishment for the aphides than earlier in the season. There is a tenth generation, and in warm early seasons probably an eleventh, but in these generations the brood is small and the "lice" grow slowly. Plant lice may be found in early December giving birth to young, which are destined to perish either when the leaves drop or through exposure to hard frost. The author has observed dead aphides of all sizes on the brown frosted leaves during early winter.

All the plant lice used for the life-history experiments were reared out of doors on young seedling walnut trees planted in pots and inclosed with glass cylinders. In 1911 the stock was procured from stem mothers collected on the earliest varieties of walnuts. When the work was started in 1911 it was too late to procure eggs, and so the data on the stem-mother cycle was acquired in 1912.

After the ninth generation no more life-history experiments were carried on in the rearing cages, but a weekly examination was made of infested leaves in the field to determine the proportions of the different forms, sexual and asexual, during the fall months.

THE OVIPAROUS OR SEXUAL FORMS.

The oviparous forms are the true sexes, comprising the winged male and the wingless oviparous, or egg-producing, female. The female aphis, after fertilization by the male, deposits true eggs, in which form alone the insect can tide over the winter months when no food supply is procurable.

As is shown in Table IV, there is no real oviparous generation, for in all the later or fall generations a certain percentage of the young will develop either into the sexed males or the sexed females. On heavily infested trees oviparous aphides appear as early in the season

as July, while on trees attacked by few lice these forms will not occur until September or October. It therefore seems that the more heavily a tree is infested the earlier will the sexed forms be produced.

A glance at Table IV demonstrates that the first oviparous form of the life-cycle material became adult September 2, and was a member of the eighth generation. In the field the first oviparous form was observed in 1911 on July 7, and in 1912 on July 9. Both of these occurred on early-leafing trees and probably belonged to the fifth or sixth generation. As the growth of the aphis colony may be said to have reached its zenith about the middle of July, it is at the time of its greatest abundance that the sexed individuals begin to appear. And, indeed, for the welfare of the species they appear none too soon, for it is in July and August that the hordes of natural enemies work tremendous havoc, frequently cleaning up a bad infestation on a tree within three weeks. Those sexual females that have gone to the trunk and limbs to deposit their eggs very often escape destruction while the others remaining on the foliage are devoured. Until the middle of August the sexual forms are comparatively rare and comprise less than 5 per cent of the whole, but after that time they become more and more abundant. The sexed females always greatly outnumber the males. Table V indicates the advance and decline of the sexual forms in the late summer and fall. The data were obtained by weekly visits to badly infested trees, during which the lice on a certain number (50) of leaflets picked out at random were counted. It must be borne in mind that as the fall advances more and more sexual females repair to the limbs for the purpose of depositing their eggs, and that therefore in the case of the later counts a really greater proportion of these were present on the trees than would appear from the records.

TABLE V.—*Comparative numbers of sexual and asexual forms of Chromaphis juglandicola observed on the foliage at different dates, San Jose, Cal., 1911.*

Date of collection.	Number of—			Percentage of—
	Viviparous forms.	Oviparous forms.	Males.	Viviparous forms.
September 15	241	247	4	49
23	258	355	5	42
30	203	143	6	58
October 7	171	66	9	70
14	166	74	14	65
24	207	117	9	62
November 2	172	111	4	60
9	420	80	11	82
16	233	36	7	84
23	10	0	0	100
Total	2,081	1,229	69	
Average				61.6

The maximum number of aphides found on a single leaflet throughout the counts was 90, of which 64 were sexual females. This occurred on the first date of collection.

It will be noticed from Table V that on the first two dates the oviparous forms were predominant but that on all later dates these were outnumbered by the viviparous individuals. On the date of the fourth collection (October 7) numerous sexual females were found on the limbs of the tree, and their number was more and more augmented each succeeding week. About October 1 the males appeared in numbers, very few of them having been in evidence previous to this time, although the first male of the season was noticed July 10. Table VI indicates the preponderance in numbers of the sexual female over the male.

TABLE VI.—*Preponderance of the sexual female of Chromaphis juglandicola over the male.*

Date of collection or count.	Number of sexual females to each male.	Date of collection or count.	Number of sexual females to each male.
September 15	62	October 24	13
23	71	November 2	28
30	24	9	7
October 7	7.3	16	5
14	5.3	23	[1]

[1] None of either sex seen on leaves.

Table VI was compiled from the same material as that used for Table V. On November 9 nearly all the sexual females were clustered on the limbs, and two weeks later they and all other plant lice at the experimental trees succumbed to a severe frost, which had at the same time withered all the leaves. This clustering of the sexual females or sexuparæ about the limbs explains the small percentage of this form as compared with the males on November 9 and 16.

Copulation seems to occur only on the leaf, and the females are not fertilized until they have passed through the last molt. A single male may fertilize several females—probably quite a large number when it is considered that the latter sex so greatly outnumbers the former and that very few eggs prove infertile. Copulation in all instances observed by the writer occupied some 30 seconds of time—a very short period for an aphis. If the male be disturbed, he will immediately retract his genital organ and move off. In 1912 the males appeared in comparative abundance in the vicinity of San Jose as early as August 26.

In general appearance the adult oviparous female differs from the viviparous form in that it is wingless, has a wider body, and bears three conspicuous transverse brown or black bands on the dorsum of the abdomen. The male is greenish-yellow, winged, with black

or dusky gray legs and antennæ. The oviparous or sexual female molts four times but does not differ in appearance from the viviparous form until the third molt is passed.

THE OVIPAROUS FEMALE, AFTER THE THIRD MOLT (FIG. 6).

Rather smaller and narrower than the full-grown form. General color pale gamboge-yellow, sometimes lemon yellow. Body twice as long as wide. Eyes bright red. Head with six erect, capitate spines on the anterior margin. Antennæ short, reaching barely to the middle of the mesothorax; 7-jointed, joint III the longest, joints IV and V subequal, joint VI longer than its spur or filament. Spur dusky, rest of antennæ pale lemon yellow. Head, thorax, and abdomen with two longitudinal rows of oval black spots on the dorsum. Thorax and abdominal segments 1–5 with two lateral longitudinal rows of circular black spots, on which are situated small tubercles bearing capitate hairs. Such tubercles also occur on the black dorsal spots. Eighth segment of the abdomen unmarked, bearing on its posterior margin a fringe of six capitate hairs. Legs pale greenish-yellow with the characteristic knee spot on the hind femora only; tarsi gray. Cornicles on the sixth segment, quite small, wider than long, pale lemon-yellow. Cauda equal in length to the hind tarsus, pale yellow, rounded. Beak very pale, almost white, reaching to the anterior coxæ. Measurements: Length of body, 1.51 mm.; width of body, 0.76 mm.; antennæ, joint I, 0.063 mm.; joint II, 0.048 mm.; joint III, 0.136 mm.; joint IV, 0.083 mm.; joint V, 0.085 mm.; joint VI, 0.086 mm.; filament, 0.021 mm.

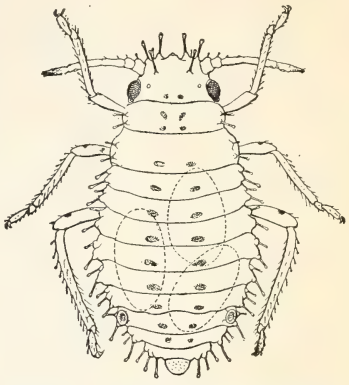


FIG. 6.—*Chromaphis juglandicola:* Oviparous female, penultimate instar. (Original.)

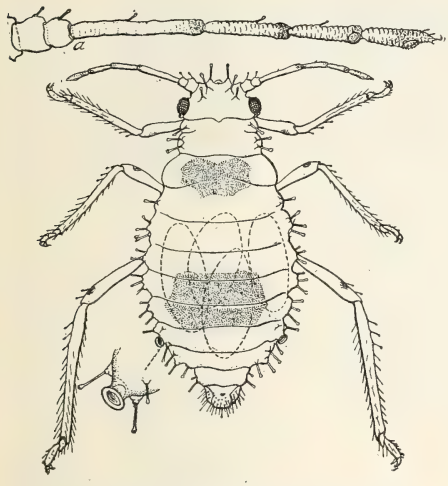


FIG. 7.—*Chromaphis juglandicola:* Oviparous female. *a*, Right antenna. (Original.)

Described from specimens collected at Walnut Creek, Cal., and San Jose, Cal., October 16 to 26, 1912.

THE OVIPAROUS FEMALE, ADULT STAGE (FIG. 7).

General color gamboge, varying in newly molted examples to lemon yellow and in older individuals to salmon pink or with a distinct brownish tint. Eyes crimson. Head and prothorax with indefinite dusky brown markings. Ocular tubercles small. Anterior margin of the head with six capitate hairs projecting forward. Thorax mottled all over with shades of brown, its lateral margins lighter. Prothorax with two capitate hairs on either side of its posterior portion. Abdomen with two or three hairs on the lateral margins of each segment. Segments 4 and 5 and posterior half of 3 with dark brown or black markings which generally coalesce to

form three transverse bars or bands, of which those on segments 4 and 5 do not quite reach the lateral margins of the segments, while that on the third segment is slightly shorter and but half as broad as the others. Wings absent. Cornicles quite similar to those of the winged viviparous female. Cauda globular, concolorous with the abdomen, larger than that of the winged viviparous female. Anal plate large, U-shaped, extending beyond the cauda when viewed from above. In reality it has a shallow incision at the apex. Antennæ on slight frontal tubercles, reaching to the middle of the metathoracic segment, white, with the apices of joints 3 to 6 black. Legs very pale yellow, almost hyaline; tarsi dusky gray at their apices. All six femora have the characteristic black or brown knee spot. Beak yellow, the extreme tip black, reaching to the second coxæ. Hind tibiæ not much swollen, bearing about 35 circular sensoria occurring evenly on the middle two-thirds of the tibia and arranged in an irregular spiral. Measurements: Length of body, 1.60 mm.; width of body, 0.81 mm.; antenna, joint I, 0.06 mm.; joint II, 0.04 mm.; joint III, 0.22 mm.; joint IV, 0.125 mm.; joint V, 0.109 mm.; joint VI, 0.081 mm.; filament, 0.023 mm. Cornicles, 0.06 mm. Cauda, 0.085 mm.

Described from specimens collected in the fall of 1911 at San Jose, Cal.

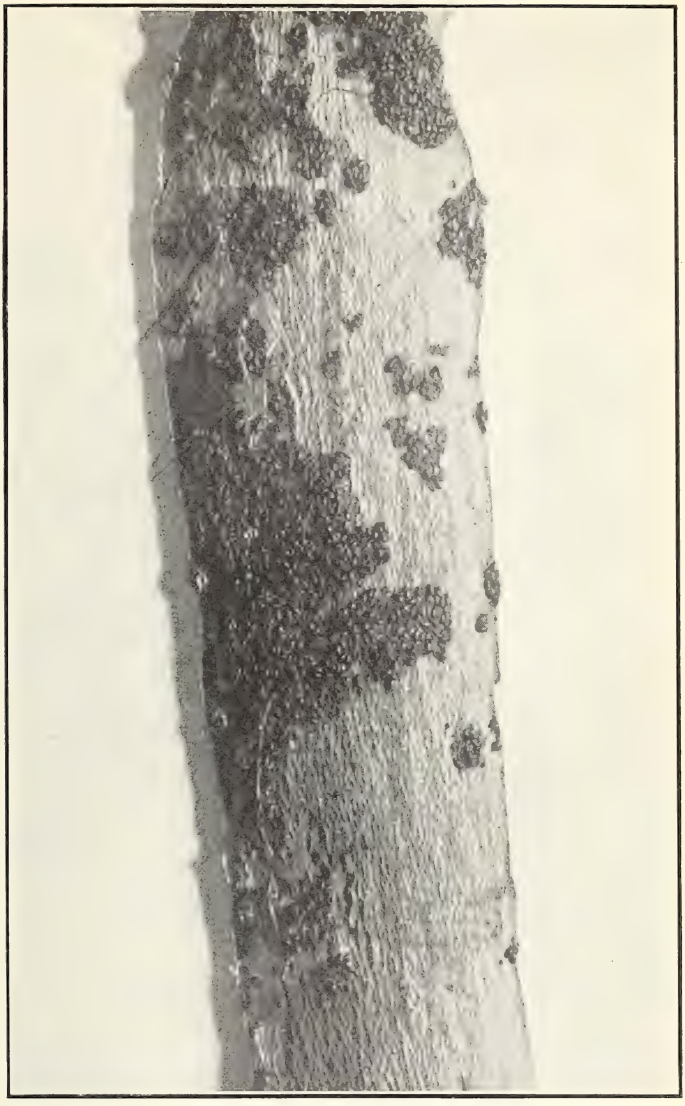
THE FULL-GROWN MALE PUPA.

In its immature stages the male pupa resembles the oviparous female. A description of a single full-grown male pupa taken at San Jose, Cal., October 27, 1912, is as follows:

General color pale lemon yellow. Antennæ pale, whitish, reaching to the anterior margin of the metathorax; last three joints black or dusky. Head and prothorax brownish. Eyes bright red. Wing pads very pale. Legs entirely whitish, only the hind femora bearing the characteristic knee spot; tarsi dusky gray. Cornicles as broad as long. Cauda very small, rounded. Cornicles and cauda pale yellow. Head, thorax, and abdomen with two longitudinal dorsal rows of oval black spots and with two such lateral rows of circular black spots. On each of these spots is situated a tubercle having a single capitate hair. Excluding the wing pads the body resembles that of the immature sexual female. Measurements: Length of body, 1.01 mm.; width of body, 0.50 mm.; antenna, joint I, 0.049 mm.; joint II, 0.035 mm.; joint III, 0.121 mm.; joint IV, 0.081 mm.; joint V, 0.087 mm.; joint VI, 0.063 mm.; filament, 0.023 mm.

THE WINGED MALE, ADULT STAGE (FIG. 8).

General color of the body pale yellow or greenish yellow. Head, prothorax, and thorax grayish black. Scutellum black. Eyes bright red. Antennæ not on frontal tubercles, reaching to the posterior margin of the first abdominal segment, pale yellow; joints I and II, the filament or spur, and the articulations of joints III to VI dusky gray. These dark articular annulations are less pronounced than in the viviparous female. Wings of medium size; costa, subcosta, and insertions pale yellowish gray; stigma short and gray, with its central area paler; veins gray, second fork of third discoidal nearer to the wing apex than to the first fork and arising beyond the apex of the stigmatic vein; stigmatic vein evenly and gently curved, absent in the middle for a space equal to one-third of its length. Legs longer in proportion to the body than those of the other forms; front legs and middle tibiæ very pale yellow or yellowish green; distal two-thirds of the middle and hind femora shaded gray, the black knee spot being present on these four femora; hind tibiæ shaded gray for its proximal three-fourths, its apical fourth pale yellow; all tarsi light gray. Abdomen barely as long as the head and thorax combined, widest at the fourth segment, and with a pair of



EGGS OF EUROPEAN WALNUT APHIS (CHROMAPHIS JUGLANDICOLA) ON PIECE OF BARK OF EUROPEAN SEEDLING WALNUT. TWICE NATURAL SIZE.

oval gray transverse spots on the fifth segment, which are separated by a space equal to their length. Cornicles pale yellow, about as broad at the base as long, very much as in the winged female. Cauda pale yellow, globular, not quite as long as the hind tarsus. Sexual organ pale yellow. Beak pale yellow, slightly exceeding the fore coxæ. Sterna black. Sensoria transversely oval, situated in an irregular row as follows; joint III, 11 to 16; joint IV, 5 to 7; joint V, 4 to 5; joint VI, 2 besides usual terminal.

Measurements: Length of body (average), 1.47 mm.; width of body (maximum), 0.48 mm.; expanse of wings (average), 4.20 mm; antenna, joint I, 0.05 mm.; joint II, 0.04 mm.; joint III, 0.34 mm.; joint IV, 0.12 mm.; joint V, 0.12 mm.; joint VI, 0.08 mm.; filament, 0.03 mm.; cornicles, 0.05 mm.

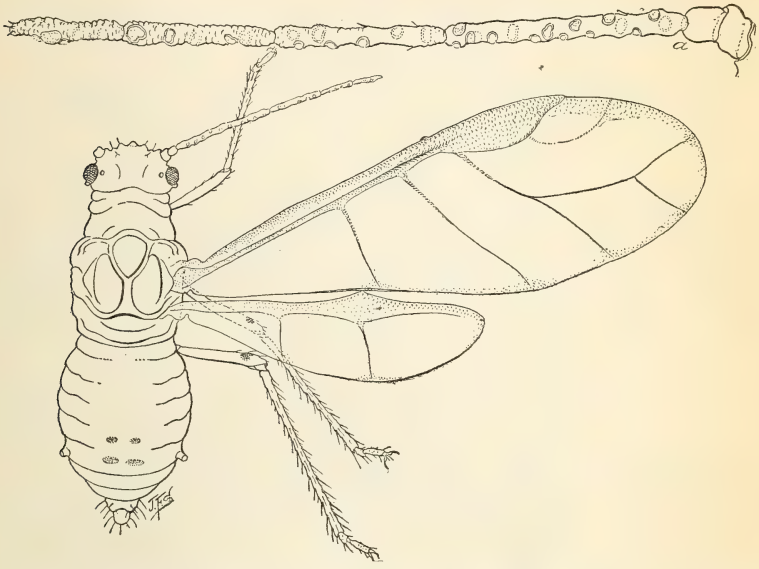


FIG. 8.—*Chromaphis juglandicola:* Winged male (appendages of left side removed). *a*, Left antenna. (Original.)

Described from many individuals collected in 1911 and 1912 at San Jose, Cal.

Both the male and the winged viviparous female when disturbed have a habit if jumping psyllid-like into the air. Their flight is generally in the form of a long spiral, and when disturbed they fly in an upward direction.

EGG DEPOSITION.

As mentioned before, the first sexual females of the year remain longer on the leaves after they have reached the adult state than those developing later. In 1911 eggs were not observed in the field until September, or seven weeks after the first appearance of sexual females. In 1912 some eggs appeared in August. This long period between the first appearance of the sexed females and the

earliest egg deposition may be explained by the fact that until late in August males are quite scarce and so the females must wait on the leaves until the males are developed. Directly after mating the female repairs to the branches and limbs to deposit her eggs. Although eggs may be deposited anywhere along the limbs, and more rarely on the newer growth, the locations most preferred are the old scars of fallen leaves and the surface of the larger limbs near their bases. Another favored location is that in the crotches of the smaller limbs. Eggs are rarely laid along the stalk of the leaf or at the base of the leaflets, and if placed in those positions they fall to the ground when the leaf drops. Cavities and interstices in the bark are also chosen, but when infestation is very severe the eggs are laid in the open on the larger limbs (see Pl. II). In such a case large groups of eggs are massed together by many females, but a single female lays not more than three or four in a group. The eggs are fastened together and to the plant surface by a thin, transparent, gluey substance. No accurate information was obtained as to the number of eggs a single aphis produced, but from general field observations together with dissections of gravid females the writer arrived at the conclusion that not more than 30 eggs fell to the share of each adult, and probably not over half that number. On July 20, 1911, five gravid females were dissected. These contained respectively 5, 3, 3, 4, and 4 well-developed ova, besides about a dozen much smaller ones. On August 28, 1912, four oviparous females dissected contained respectively 2, 2, 4, and 2 full-grown ova besides about 20 much smaller ones. All these individuals were taken on the leaves and had not oviposited. The largest eggs dissected were lozenge-shaped and measured 0.37 mm. in length by 0.14 mm. in width.

THE EGG (FIG. 1; PL. II).

When first laid, the egg is pale lemon-yellow or whitish yellow, oval, almost twice as long as broad, flatter than most eggs of Aphididæ, and slightly broader at the micropylar end. After two or three days it turns black and shines obscurely when placed under a strong light. The surface is beautifully sculptured with granular hexagonal markings. These markings are thickened portions of the shell. The narrow intermediate portions of the shell are extremely thin, so much so that four months after the egg has been laid the yellow interior substance is plainly visible through them if subjected to a high power of magnification. It appears that about 85 per cent of the eggs are fertile. The average size is 0.50 mm. by 0.28 mm. The egg stage may be said to occupy, on the average, five months in California.

ANT ATTENDANTS.

The sweet juices excreted by the European walnut aphis attract large numbers of ants, of which a large black species, *Formica subsericea* Say, is the most abundant. The author is indebted to Mr. Theo. Pergande, of the Bureau of Entomology, Washington, D. C., for the determination of this species.

THE AMERICAN WALNUT APHIS (Monellia caryae Monell).[1]

Callipterus[2] *caryae* Monell, U. S. Geol. & Geog. Survey Bul. 5, No. 1, p. 31, Jan. 22, 1879.

Monellia[3] *caryae* Gillette, Jour. Econ. Ent., v. 3, No. 4, p. 367, fig. 6, Aug., 1910.

HISTORY OF THE SPECIES.

This plant-louse was first collected in Missouri by Mr. J. T. Monell in 1879. His original description is as follows:

Winged form; general color pale yellow; tips of antennal joints black; legs entirely pale whitish. Antennæ a little shorter than the body; seventh joint equal to or one-third longer than the preceding; fifth joint as long as the two following taken together. Nectaries not perceptible. Rostrum not reaching to the middle coxæ. Wings hyaline, veins pale; stigma rather short and blunt at the apex. Stigmal vein subobsolete, its course being only traced with difficulty. The distance between the apex of the lower cubital branch and that of the second discoidal equal to about one-half the distance between the apices of the first and second discoidals. Apterous viviparous females and pupæ with four rows of tubercles, each mounted with a capitate bristle.

Leaves of walnut, hickory and pecan. June–July, St. Louis, Mo.

This aphis has been reported from Illinois (Thomas, 1880; Davis, 1910), Nebraska (Williams, 1910), Oregon (Gillette, 1910), and Michigan (Gillette, 1910), and doubtless occurs in America wherever its food plants grow.

GENERAL DESCRIPTION; CHARACTER AND EXTENT OF INJURY.

This aphis is about one-sixteenth of an inch long and about one-third as wide and is generally of a pale lemon-yellow color. It occurs on the lower surface of the leaf and on the nutlets of the eastern black walnut tree and crosses derived from it. When infestation is severe, the aphides will also be found on the upper surface of the leaves. The species, according to Mr. Monell and other writers, feeds also on hickories and pecan. The character and extent of its injury is altogether similar to that of the European walnut aphis (*Chromaphis juglandicola* Kalt.). This plant-louse does not lie so flatly appressed to the plant surface as the European species and is much more active, bearing longer legs and antennæ in proportion

[1] Mr. J. T. Monell, of the Bureau of Entomology, has kindly identified the specimens sent to him by the author as *Monellia caryae* Monell.

[2] The genus Callipterus ("beautiful-winged") was erected by Koch (1855).

[3] The genus Monellia was erected by Oestlund (1887), with *caryella* Fitch as the type species.

to the size of the body. When on the lower surface of the leaflet it has the habit of resting with the head directed straight toward the peduncle of the leaflet. In July and August, in which months this insect is most abundant, as many as 400 individuals may be found on one leaflet, 5 per cent of which will be resting on the upper side. At this time it is much sought after by ants, which feed on the liquid excreted by it. A large red and black species, determined by Mr. Theodore Pergande as *Formica obscuriventris* Mayr, is a very common attendant. *Formica subsericea* Say also attends it. The sweet excretions of the aphis attract many flies of the families Muscidæ, Anthomyiidæ, Oscinidæ, and Syrphidæ, many large bees including the honeybee, wasps of the family Pompilidæ, and parasitic wasps of the families Ichneumonidæ and Braconidæ, and numerous smaller forms of insect life. The author first observed this aphis on July 20, 1911, at San Jose, Cal.

LIFE HISTORY AND TECHNICAL DESCRIPTIONS.

The Viviparous or Asexual Forms.

The stem-mothers hatch as soon as the buds start to swell, about the 1st of April. These develop into winged aphides and pass their life cycle in from 25 to 30 days, according to temperature and the amount of food supply. The viviparous aphis passes through four molts, becoming winged after the final one. Table VII indicates the life cycle of 38 individuals of the summer generations.

Table VII.—*Life-cycle of viviparous females of Monellia caryae, summer generations, San Jose, Cal., 1912.*

No. of individual.	Generation.	Date of deposition.	Date of acquiring wings.	Life cycle.	No. of individual.	Generation.	Date of deposition.	Date of reaching maturity.	Life cycle.
				Days.					*Days.*
1	II	Apr. 22	May 12	20	20	V	June 22	July 7	15
2	II	22	12	20	21	V	23	7	14
3	II	22	12	20	22	V	23	7	14
4	II	May 1	20	19	23	V	24	7	13
5	II	1	22	21	24	V	24	7	13
6	II	1	23	22	25	V	24	7	13
7	II	1	23	22	26	V	24	8	14
8	III	13	29	16	27	V	24	8	14
9	III	13	29	16	28	V	24	8	14
10	III	13	29	16	29	V	25	8	13
11	III	13	29	16	30	V	25	8	13
12	III	13	29	16	31	V	25	8	13
13	III	13	30	17	32	V	25	8	13
14	III	13	30	17	33	V	25	9	14
15	III	13	30	17	34	V	27	10	13
16	III	13	30	17	35	V	27	10	13
17	III	13	30	17	36	V	27	10	13
18	V	June 22	July 4	12	37	V	27	10	13
19	V	22	7	15	38	VI	July 13	Aug. 1	19

Thus, the second generation requires 20 days, the third 16 or 17, and the fifth 15, in which to complete the life cycle. Records of the fourth generation were not obtained owing to premature death of all

individuals of this generation of which the date of deposition had been ascertained. Individuals of the fourth generation probably mature in an average of 16 days. The leaves of the Eastern black walnut fall earlier than those of the European or California black types, and consequently the viviparous aphides are not found so late on the trees. There are probably not more than nine generations of these in a year.

Immediately after passing the final molt the aphides begin depositing young. These are entirely pale lemon-yellow with red eyes and four longitudinal rows of capitate hairs and do not exceed 0.70 mm. in length. From 10 to 20 young are produced by a single female, dependent on the season of the year. The earlier generations are more prolific. After midsummer the progeny becomes smaller and smaller with successive broods.

THE PUPA OF THE WINGED VIVIPAROUS FEMALE (FIG. 9).

After the second molt the pupal wing pads are apparent as small emarginations on the sides of the thorax, but after the following molt they are much more readily seen. The pupa of the winged viviparous female may be described as follows:

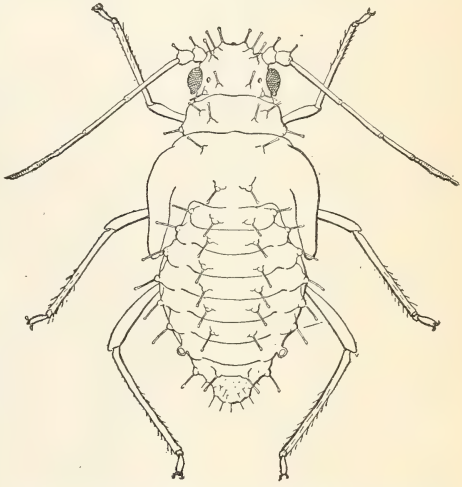


FIG. 9.—*Monellia caryæ:* Pupa of winged viviparous female. (Original.)

Color generally pale lemon-yellow, sometimes white; head often with a reddish tinge. Antennæ on small frontal tubercles, pale yellow, with the filament and articulations of joints 3 to 6 dusky black. Eyes bright red. Thoracic segments and wing pads light yellow, wing pads projecting out from the body at a very acute angle. Legs pale, tarsal apices dusky. Body beset with long capitate spines in four rows. Cornicles on segment 6 of the abdomen, hardly perceptible, broader than long. Cauda blunt, conical, and short. Cornicles and cauda concolorous with the abdomen. Beak pale, reaching to the middle coxæ. Measurements: Length of body (average), 1.87 mm.; width of body (average), 0.71 mm.; antenna, joint I, 0.058 mm.; joint II, 0.050 mm.; joint III, 0.287 mm.; joint IV, 0.207 mm.; joint V, 0.201 mm.; joint VI, 0.128 mm.; filament, 0.136 mm.

This pupa is distinguishable from that of Chromaphis by the presence of the dorsal rows of spines and by the absence of the black femoral spots. The penultimate instar occupies on the average four or five days. At its termination the final molt occurs, and after this the insect has acquired its full development.

THE WINGED VIVIPAROUS FEMALE (FIG. 10).

General color pale lemon-yellow; many examples are greenish yellow and others decidedly pinkish. Head, thoracic lobes, and scutellum pale brown or yellowish brown. Eyes pink. Antennæ on small frontal tubercles, about half as long as the body, pale yellow, with articulations of joints III to VI black; joint III the longest, not noticeably thickened basally; joint IV slightly longer than V and barely as long as joint VI, together with its spur or filament. Bases of antennæ encircled, in the majority of individuals, with a narrow dusky ring. Close to the lateral margins of the prothorax and roughly parallel to them occur two narrow black lines. (These are sometimes absent.) Wings of moderate size; costa, subcosta, and stigma pale yellowish green, other veins light brown, of medium thickness. Stigmatic vein entirely subobsolete, its course not easily made out. Legs very pale, whitish, tarsi and apex

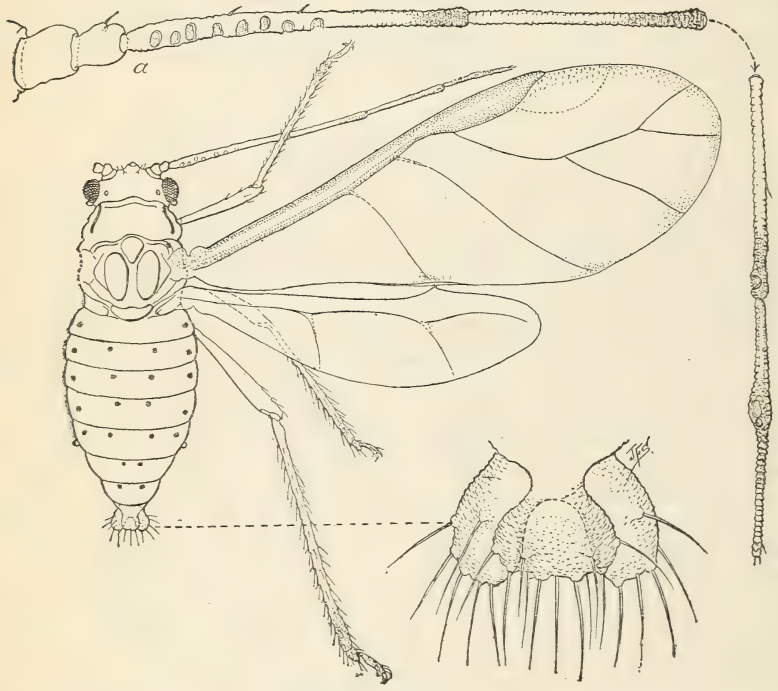


FIG. 10.—*Monellia caryæ:* Winged viviparous female. *a*, Antenna. (Original.)

of tibiae dusky grey; anterior and posterior femora in about half of the individuals bear a grey knee spot quite like that of *Chromaphis juglandicola* Kalt. but smaller. This spot never occurs on the middle femora. Abdomen pale yellow, sometimes greenish and at other times reddish, with four rows of small black spots, which are very variable and often wholly absent. The two lateral rows have larger spots and these are found on segments 2–6; the two median rows are smaller and their spots exist on segments 2–8. Cornicles on segment 6, hardly perceptible, more than twice as broad as long, about 0.008 mm. long. Cauda globular, shorter than the hind tarsus. Cornicles and cauda concolorous with the abdomen. Anal plate bifid, armed with spines. Beak pale, extreme tip brown and not quite extending to the second pair of coxæ. Sensoria occur on the antennæ as follows: Joint III, 6–9 transversely oval on basal half or two-thirds of joint; in an equally spaced row; joint V, 1 terminal; joint VI, 4 terminal (1 large, 3 small). Measurements: Length of body, 2.16 mm.; width of

body, 0.754 mm.; wing expanse, 4.44 mm. Antenna, joint I, 0.076 mm.; joint II 0.060 mm.; joint III, 0.416 mm.; joint IV, 0.273 mm.; joint V, 0.273 mm.; joint VI, 0.143 mm.; filament, 0.164 mm.

Described from many specimens taken at San Jose, Cal., during 1911 and 1912.

The complete absence of the stigmatic vein and the relatively longer antennæ, together with the diminutive cornicles, will readily distinguish this species from the European walnut aphid.

In 18 months' study of this plant-louse the author has failed to find any trace of the existence of a wingless viviparous form.

The Oviparous or Sexual Forms.

If a tree be heavily infested, the sexual forms appear first about the middle of July and probably belong to the fifth and sixth generations. If infestation be only moderate or slight, these forms are not produced until several weeks later and will be members of the seventh and following generations. The sexed forms from the beginning are produced in comparative abundance and comprise from 30 to 50 per cent of the whole. The young sexed females are paler and more spindle-shaped than the young of the viviparous individuals, while the male larvæ and pupæ are conspicuously brick-red in color. The male is not so greatly outnumbered by the female as in the European walnut aphis, and from the first comprises from 20 to 30 per cent of the sexed insects. On August 26 and 27 and September 5, 1912, a count of the forms on 34 leaflets taken at random from an Eastern black walnut tree showed 177 viviparous females, 14 males, and 26 sexed females. Probably as many again of the sexed females in proportion to the leaflets counted could be found on the twigs ovipositing. Copulation takes place on the leaf and occupies half a minute. All through August and September, 1912, the oviparous females were observed on the twigs, but few eggs were found until September. After the middle of September few aphides were found, the great majority having been destroyed by their natural enemies, but those that escape perpetuate the species until the leaves fall in November. The majority of aphides born in the late fall are sexual. The sexed female shortly after mating becomes much swollen by reason of the growing ova in her body, and the last four abdominal segments become orange colored. She repairs to the twigs and limbs and wanders around searching for locations wherein to oviposit. Occasionally immature females wander off to the twigs, but later return to the leaves to resume feeding. The fully mature fertilized oviparous female once she has forsaken the leaf rarely if ever returns, and thus escapes many predatory foes. Having found a crevice or crack in the cortex suitable for her purpose she grips the limb with

her six legs and bends the hind part of the abdomen at a right angle to the rest of the body and then gives her abdomen a succession of jerks to get it into place. This performed to her satisfaction, she remains motionless for 60 seconds while the egg is being extruded, and after depositing it walks off. The writer has never seen the eggs of this species placed in an open situation, but always in some protected position in the bark. On August 28, 1912, four gravid females were dissected and were found to contain respectively 3, 4, 2, and 4 large eggs, and all had several smaller ones. Another had 8 large eggs in her ovaries and was greatly distended therefrom. The egg is bluntly oval, bright yellow when first laid, but changing in a day or two to black and obscurely shining. It measures 0.35 mm. in length and 0.17 mm. in width, and is therefore considerably smaller than the egg of the European walnut plant-louse. The oviparous forms are described below.

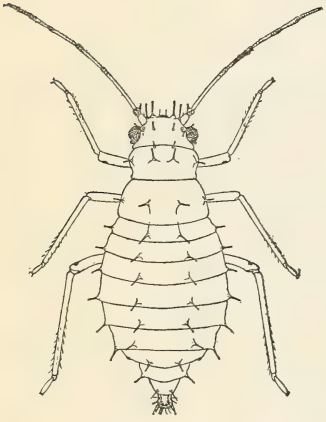


FIG. 11.—*Monellia caryæ:* Oviparous female. (Original.)

THE OVIPAROUS FEMALE, FULL GROWN (FIG. 11).

General color pale greenish yellow or sometimes greenish white, the four apical segments of the abdomen at first colored like the rest of the body and later orange colored. Body rather narrow, not at all flattened, the sides nearly parallel and produced posteriorly into a conical tube. Antennæ a little over one-half the body in length, pale, with the apical third or fourth of joints III to VI dusky gray; joint II gray and armed with a capitate spine on its inner margin; joint III longest; joints IV and V subequal; joint VI shorter than its spur or filament. Legs very pale yellow, with a dark spot close to the apex of the anterior and posterior femora. (In many individuals these spots are absent.) Eyes pink. The arrangement of capitate spines is as follows: The head bears eight, the prothorax six, the mesothorax, metathorax, and abdominal segments 1 to 5, inclusive, four, and abdominal segments 6, 7, and 8 two; these spines appear as four longitudinal rows. Cornicles greenish yellow, broader than long, hardly perceptible, located on segment 6. Cauda concolorous with the body, globular, armed with four noncapitate spines, half as long as the hind tarsus. Genital plate protruding beyond the cauda, pale, its margin beset with short noncapitate hairs. Beak pale, its extreme tip brownish, just exceeding the second pair of coxæ. Measurements: Length of body, 1.68 mm.; width of body, 0.72 mm.; cauda, 0.038 mm.; antenna joint I, 0.04 mm.; joint II, 0.035 mm.; joint III, 0.300 mm.; joint IV, 0.17 mm.; joint V, 0.17 mm.; joint VI, 0.100 mm.; filament, 0.12 mm.

Described from many specimens collected at San Jose, Cal., during 1912.

YOUNG MALE PUPA.

Light red in general color; appressed closely to the leaf surface. Dorsum of head in front black, behind gray. Dorsum of thorax gray. Antennæ six-jointed (i. e., with five joints and filament), one-third as long as the body, pale gray. Eyes bright red. Legs pale, femora dusky gray. Mesothorax, metathorax, and first five abdominal segments each with four black spots in a transverse row. Abdominal segments 6 to 8, inclusive, with two such spots. A single capitate spine arises from each of these spots. Cornicles imperceptible. Cauda pale, short, conical. Beak pale, tip dusky gray, reaching first coxæ.

FULL-GROWN MALE PUPA (FIG. 12).

General color pale brick red; head pale orange. Antennæ half as long as the body, seven-jointed, pale yellow, with dusky articulations. Eyes bright red. Legs very pale, femora usually slightly dusky. Wing pads white. Whole body with four longitudinal rows of dark capitate spines distributed as in the oviparous female. Cornicles on segment 6, appearing as little rims on the body surface, broader than long, concolorous with the body. Cauda bluntly conical, very short, pale yellow. Beak pale yellow, extreme tip brown, reaching to the first pair of coxæ. Measurements: Length of body, 1.58 mm.; width of body, 0.57 mm.; cauda, 0.045 mm. Antenna, joint I, 0.071 mm.; joint II, 0.054 mm.; joint III, 0.257 mm.; joint IV, 0.173 mm.; joint V, 0.200 mm.; joint VI, 0.12 mm.; filament, 0.12 mm.

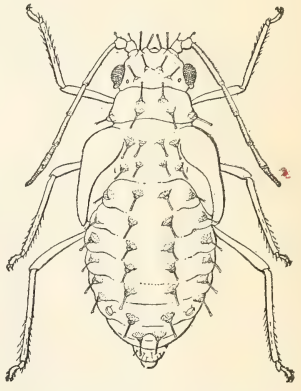


FIG. 12.—*Monellia caryæ:* Male pupa. (Original.)

Described from several specimens collected at San Jose, Cal., in 1912.

WINGED MALE (FIGS. 13; 18, *a*).

General color pale lemon-yellow or greenish yellow; head and a median quadrilateral area on thorax dark brown; scutellum dark brown; eyes dark red. Antennæ not mounted on frontal tubercles, about as long as the body; joints I and II with a dusky central part; joints III to VI pale, with their apices dusky gray; filament pale; joint III longest, bearing about 24 small oval sensoria; joints IV and V subequal, both bearing 10 to 15 small sensoria arranged along the outer margin; joint VI bearing 4 sensoria, of which the most distal is apical; joint VI longer than the filament, the two together scarcely as long as joint V. Ocelli distinct. Wings of medium size; costa and insertions greenish yellow; stigma short and moderately broad, dusky gray, with a large paler central area; veins brown, the third discoidal curving considerably to meet its second fork; second fork twice as near to the first fork as to the apex of the wing; stigmatic vein obsolete in its middle portion. Legs longer in proportion to the body than in the winged viviparous female, pale greenish yellow, with a large dusky area near the apex of all six femora; apices of tibiæ and tarsi dusky gray. Abdomen short, not quite as long as the head and thorax together, widest at the third segment; segments 1 to 7, inclusive, with two lateral black spots, one on each side; segments 1 to 6, inclusive, and segment 8 with two dorsal black spots, one on either side of the dorso-median line; the lateral spots on segments 1 to 6, inclusive, are circular or subcircular; the dorsal pairs on these segments are oval; the dorsal spots on segments 6 and 8 coalesce narrowly in the middle. Cornicles on segment 6, hardly perceptible, broader than long. Cauda globular, dusky, half as long as the hind tarsus. Repro-

ductive organ white, when extended about as long as antennal joint IV. Beak pale yellow, extending a little beyond the first pair of coxæ. Sterna and apical half of the underside of the head dark brown. Very often one or more of the dusky abdominal spots are absent. Measurements: Length of body, 1.39 mm.; width of body, 0.69 mm.; wing expanse, 4.10 mm.; cauda, 0.049 mm.; antennal joint I, 0.051 mm.; joint II, 0.058 mm.; joint III, 0.362 mm.; joint IV, 0.238 mm.; joint V, 0.240 mm.; joint VI, 0.114 mm.; filament, 0.134 mm.

Described from four specimens collected at San Jose, Cal., in 1912.

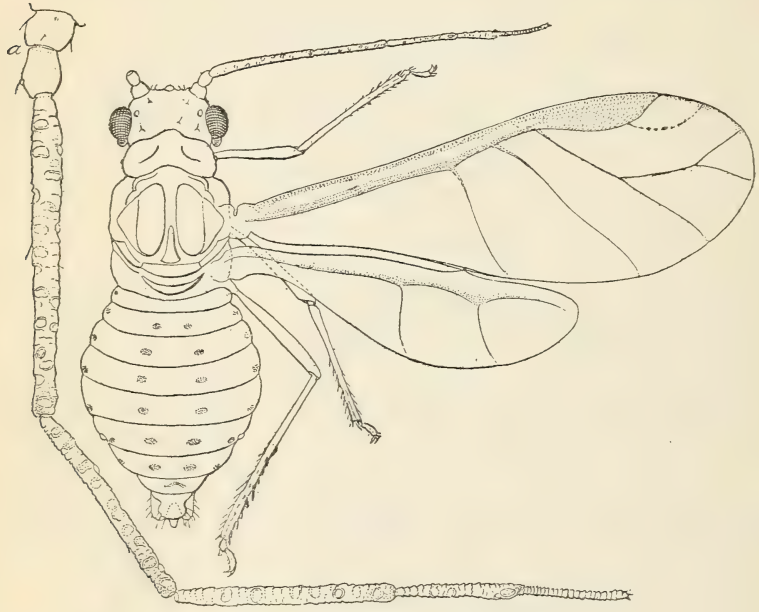


FIG. 13.—*Monellia caryæ:* Winged male. *a*, Left antenna. (Original.)

THE LITTLE HICKORY APHIS (Monellia caryella Fitch).

Aphis caryella Fitch, [First] Report on the noxious, beneficial, and other insects of the State of New York, Albany, p. 163–165, 1855.

Callipterus caryellus Fitch, Third report on the noxious and other insects of the State of New York, Albany, p. 448–449, 1856.

Monellia caryella, Oestlund, Geol. & Nat. Hist. Survey Minn. Bul. 4, p. 45, 1887.

HISTORY OF THE SPECIES.

The little hickory aphis was first collected in New York State by Dr. Asa Fitch, previous to the year 1855. The following is Fitch's original description:

The Little Hickory Aphis (*Aphis caryella*) is pale yellow with white antennæ which are alternated with black rings, the wings are transparent and without spots, their veins slender and pale yellow, the legs yellowish white to their ends. Length 0.12 to the tips of the wings. The abdomen is depressed, egg-shaped, its apex slightly

narrowed and elongated. The antennæ are longer than the body, tapering, seven-jointed; two basal joints as broad as long, twice the diameter of the following joints; third joint longest, slightly thicker towards its base; fourth and fifth joints rather shorter than the third, cylindric; two last joints together about equalling the fifth in length; the sixth swelled at its tip into a long oval knob, the seventh more slender but not capillary, shorter than the sixth; a broad black band at the base of the third and each of the following joints. First vein of the fore wings straight and almost transverse; second vein bent near its base, running first towards the apex and then turning rather abruptly and continuing straight to the inner margin, more than twice as far from the first at tip as base; third vein arising from the stigma near its anterior end, and not from the rib-vein forward of the stigma, as it does in the aphides generally, except those pertaining to this group, its base and its apex about the same distance from the second vein that this is from the first, forking rather forward of its middle, strongly bent at this point, and from hence to its tip parallel with the third vein or but slightly diverging from it, its tip a third nearer that of the third vein than this is to the second; second fork nearer the fourth vein at tip than to the first fork, the triangular cell between it and the first fork with its three sides equal; fourth vein short and often nearly abortive, shorter than the second fork, equally curved through its whole length, its tip much nearer that of the rib-vein than that of the second fork; rib-vein very slightly diverging from the margin from the base to the stigma, curved from thence to its tip. Stigma oval, about twice as long as wide, watery, sometimes tinged with yellowish. A variety has the stigma dusky at its tip. Another variety (*costalis*) has the rib-vein coal black interrupted with whitish towards the stigma, which is dusky and black at each end.

In a general discussion of this species before his description Fitch refers to the minute cornicles characteristic of this and kindred species. In his third report on the insects of New York he mentions the European walnut aphis and says "European *C. juglandicola* of Koch" [*Chromaphis juglandicola* Kalt.] "appears closely related to this present species" [i. e. *Callipterus caryellus*]. Fitch gave the host plant of his species as the hickory. Oestlund (1887) reports it in Minnesota from *Carya amara* Nutt. Davis (1910) and other Eastern writers record it from hickory in the Eastern States. In California the normal food plants are the California black walnut (*Juglans californica*) and hybrids derived from this tree.

GENERAL APPEARANCE; CHARACTER AND EXTENT OF INJURY.

In general appearance this aphis is very similar to the American walnut aphis (*Monellia caryæ* Monell) and can not be distinguished from it except when viewed under the microscope or a powerful hand magnifier. Its habits of life and the character and extent of its injury are also very similar to those of *M. caryæ*. The writer had observed this aphis for several months before he realized that it was a distinct species and not a variety of *caryæ*, as he had previously supposed. When the sexed forms appeared it was noticed that the oviparous female of *caryella* differed markedly from the same form of *caryæ*, and this led to a closer scrutiny of the viviparous form resulting in the establishment of the points of divergence shown in Table VIII.

TABLE VIII.—*Divergences of structure between Monellia caryæ Monell and M. caryella Fitch.*

Form.	*Monellia caryæ* Monell.	*Monellia caryella* Fitch.
Winged viviparous female	Antennal joint III very slightly thickened basally. Sensoria on antennal joint III occupying basal half or two-thirds. Antennal joint VI and its spur or filament subequal, or VI less than spur. Dusky knee spots often present.	Antennal joint III quite noticeably thickened for its basal half. Sensoria on antennal joint III occupying basal third. Antennal joint VI one-third as long again as its spur or filament. Dusky knee spots absent.
Pupa of viviparous female	Four longitudinal rows of capitate spines.	Six longitudinal rows of capitate spines.
Oviparous female	Smaller than the viviparous female. Four longitudinal rows of capitate spines.	Larger than the viviparous female. Six longitudinal rows of capitate spines.

LIFE HISTORY AND TECHNICAL DESCRIPTIONS.

Life-history studies on this plant-louse began in August, 1912, at San Jose, Cal., but no rearing work was done until the appearance of the sexed forms in September. Observations taken in August and September indicated a development of the summer generations similar to that found in *Monellia caryæ*. This was further confirmed by studies during 1913. The sexed forms were studied at Walnut Creek and San Jose, Cal. In both localities these did not appear until late in September, even on trees heavily infested. The aphides remained on the trees as long as there were leaves on which they could subsist and were to be found until mid-November. After September the great majority of aphides deposited were oviparous, and of these the males were extraordinarily scarce, the writer observing only one individual of this sex among hundreds of oviparous females. Table IX indicates the life cycle of plant-lice deposited by four viviparous females and shows the preponderance of the sexed form over the asexual in the late fall.

TABLE IX.—*Life-cycle record of the progeny of four viviparous females of Monellia caryella, Walnut Creek, Cal., 1912.*

FEMALE NO. 1; DEPOSITED 3 YOUNG.

No. of larva.	Date of—					Form of individual.	Life cycle.
	Hatching.	Molt 1.	Molt 2.	Molt 3.	Molt 4 (becoming adult).		
							Days.
1	Oct. 4	Oct. 7	Oct. 10	(?)	Oct. 16	Winged viviparous female.	12
2	4	7	11	(?)	18	Oviparous female	14
3[1]						do	

FEMALE NO. 2; DEPOSITED 6 YOUNG.

1	Oct. 12	Oct. 15	Oct. 18	Oct. 21	Oct. 28	Oviparous female	16
2	12	15	18	21	28	do	16
3	12	15	19	22	29	do	17
4	12	15	19	23	30	do	18
5	12	(?)	(?)	(?)	29	do	17
6	12	(?)	(?)	(?)	30	do	18

[1] Died permaturely.

TABLE IX.—*Life-cycle record of the progeny of four viviparous females of Monellia caryella, Walnut Creek, Cal., 1912*—Continued.

FEMALE NO. 3; DEPOSITED 16 YOUNG.

No. of larva.	Date of—					Form of individual.	Life cycle.
	Hatching.	Molt 1.	Molt 2.	Molt 3.	Molt 4 (becoming adult).		
							Days.
1	Oct. 16	Oct. 21	Oct. 27	Nov. 3	Nov. 7	Oviparous female	22
2	16	21	27	3	7	do	22
3	16	21	27	3	7	do	22
4	17	(?)	(?)	(?)	8	do	22
5	17	(?)	(?)	(?)	8	do	22
6	17	(?)	(?)	(?)	8	do	22
7	17	(?)	(?)	(?)	8	do	22
8	18	(?)	(?)	(?)	8	do	21
9	18	(?)	(?)	(?)	9	do	22
10[1]						do	
11[1]						do	
12[1]						do	
13[1]						do	
14[1]						do	
15[1]						do	
16[1]						do	

FEMALE NO. 4; DEPOSITED 8 YOUNG.

1	Oct. 18	Oct. 22	Oct. 27	Nov. 2	Nov. 7	Oviparous female	20
2	18	22	27	3	9	do	22
3	18	22	27	4	9	do	22
4	18	22	27	4	9	do	22
5[1]						do	
6[1]						do	
7[1]						do	
8[1]						do	

[1] Died prematurely.

SUMMARY.

Life cycle (20 oviparous females).	Days.
Maximum	22
Minimum	14
Average	18.92
First instar (13 individuals), average	3.7
Second instar (13 individuals), average	4.5
Third instar (11 individuals), average	5.7
Fourth instar (11 individuals), average	5.6

The viviparous forms, so far as the author has observed, all develop wings.

The eggs of this aphis are larger than those of the American walnut aphis and measure on the average 0.536 mm. in length and 0.222 mm. in maximum width. They are elongate-oval in shape, rather feebly shining, and have a softer shell than is found in the eggs of the majority of plant-lice, but one not so soft as is that of *Chromaphis juglandicola*. They are placed either singly or in groups of two or three around the axils of the buds or in crevices in the bark and in scars caused by fallen leaves on the smaller limbs and twigs. Oviposition is in progress during the months of October and November, each oviparous female laying on the average about 12 eggs. Owing to the

scarcity of males in the fall of 1912 at Walnut Creek, Cal., it seemed very probable that a large proportion of the eggs would prove to be sterile, and in the following spring examinations of egg-infested trees showed this assumption to be correct.

The Viviparous Forms.

The stem-mothers commence hatching very shortly after the leaf buds open in the latter part of March. Previous to the first molt they are pale lemon-yellow with red eyes, hyaline legs, and dusky tarsi; the joints of the antennæ have black articulations; on the abdomen are four longitudinal rows of circular dusky spots from each of which arises a capitate spine. They are destined to become winged and in their later stages do not differ from the summer winged viviparous individuals.

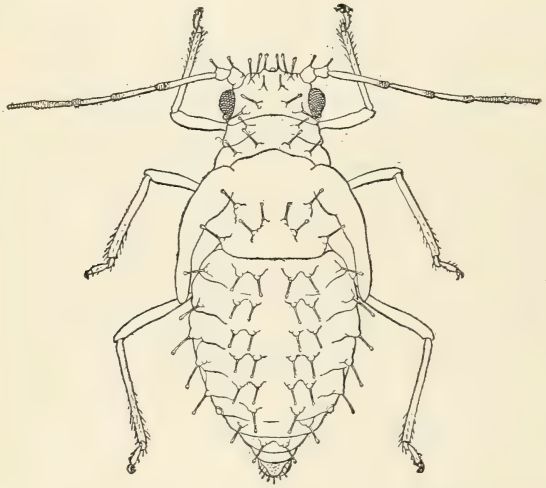


Fig. 14.—*Monellia caryella:* Pupa of winged viviparous female. (Original.)

THE PUPA OF THE WINGED VIVIPAROUS FEMALE (FIG. 14).

General color pale lemon-yellow; some individuals exhibit a decided greenish, others a decided salmon colored tinge. Antennæ two-thirds of the body in length; apices of joints III to VI and the whole filament dusky, otherwise pale yellow, almost white. Eyes bright red. Head with eight capitate spines, six of these on the frontal margin and two near the hind border. Prothorax with six capitate spines, two of these near the middle of the segment and four in a transverse row along the hind margin. Mesothorax, metathorax, and abdomen with six longitudinal rows of capitate spines. Legs pale yellow, tarsi dusky. Wing pads pale, after being imbedded in balsam for a few days becoming dusky. Cornicles barely perceptible, wider than long. Cauda rounded, not as long as the hind tarsi and without hairs. Beak pale with a brown tip, almost reaching the second pair of coxæ. Measurements: Length of body, 1.81 mm.; width of body, 0.72 mm.; antenna, joint I, 0.070 mm.; joint II, 0.050 mm.; joint III, 0.253 mm.; joint IV, 0.198 mm.; joint V, 0.183 mm.; joint VI, 0.134 mm.; filament, 0.105 mm.

Described from four specimens, Walnut Creek, Cal., October, 1912.

THE WINGED VIVIPAROUS FEMALE (FIG. 15).

General color pale lemon-yellow, somewhat varying in shade. Antennæ about four-fifths as long as the body, pale yellow, with joints III to VI, inclusive, bearing an apical black ring (on joint III this ring is narrower than the other joints); filament of joint VI dusky; joint III is the longest; joints IV and V subequal or joint IV slightly longer than V; joint IV about four-fifths as long as III; joint VI together with its filament about equal to V; filament about three-fourths as long as VI; basal third of joint III noticeably swollen and bearing from five to seven oval transverse sensoria; usual apical sensoria on both joints V and VI. Head pale yellow, with the frontal margin black. Eyes bright red. Prothorax pale yellow, with two narrow, black, longitudinal stripes arising from the anterior angles and extending for two-thirds

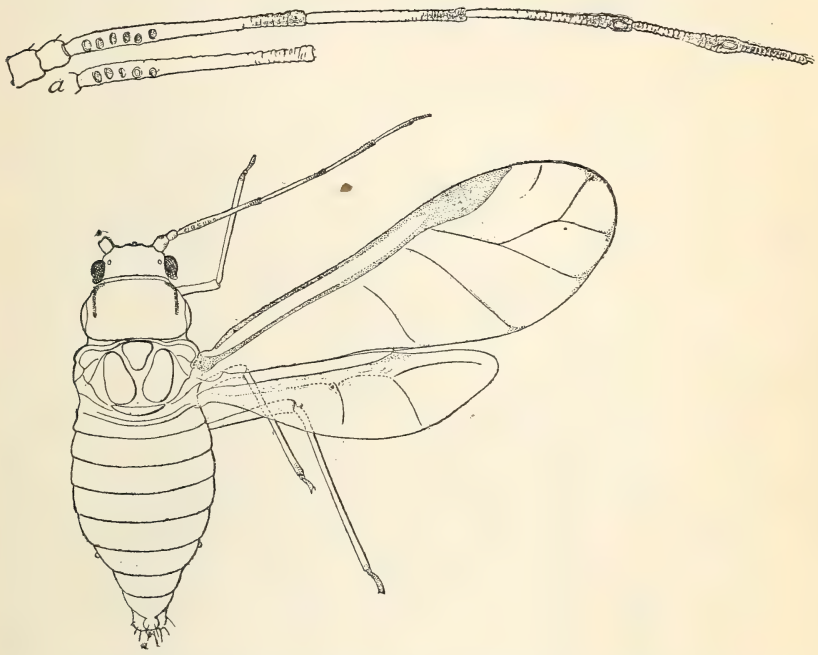


FIG. 15.—*Monellia caryella:* Winged viviparous female. *a*, Right antenna, enlarged, with variations of number of sensoria. (Original.)

of its width. Thoracic lobes and scutellum light brown, sometimes with a salmon-pink tinge. Wing insertions, costa, subcosta, and stigma pale lemon-yellow; discoidals yellowish-brown; first and second discoidals heavier than the other veins; third discoidal obsolete at its immediate base, its first fork equidistant from the second fork and the base of the discoidal, its second fork nearer to the first fork than to the apices of its two branches; branches of second fork equal in length; stigmatic vein very weak, its basal half traceable only with difficulty; lower wing colorless. Legs pale yellow; tarsi and tibial apices dusky. Abdomen entirely pale lemon-yellow, the body widest at the third segment. Body somewhat narrowed laterally. Cornicles pale yellow, hardly perceptible, wider than long. Cauda globular, bearing a fringe of weak hairs, about equal in length to the hind tarsi, concolorous with the abdomen. Genital plates armed with weak hairs, pale yellow. Beak pale yellow, its extreme tip brown, extending halfway between first and second coxæ. Measure-

ments: Length of body (average), 1.67 mm.; width of body (average), 0.61 mm.; wing expanse (average), 4.02 mm.; antenna, joint I, 0.053 mm.; joint II, 0.046 mm.; joint III, 0.41 mm.; joint IV, 0.335 mm.; joint V, 0.32 mm.; joint VI, 0.191 mm.; filament, 0.123 mm.; cauda, 0.084 mm.; Cornicles, 0.009 mm.

Described from numerous specimens, Walnut Creek, Cal., October, 1912.

The Oviparous Forms.

THE OVIPAROUS FEMALE (FIG. 16).

Wingless. General color pale lemon-yellow, in mature individuals the central part of the abdomen diffused with orange. Body elliptical, widest at the third abdominal segment. Antennæ half as long as the body, not on frontal tubercles, pale, with

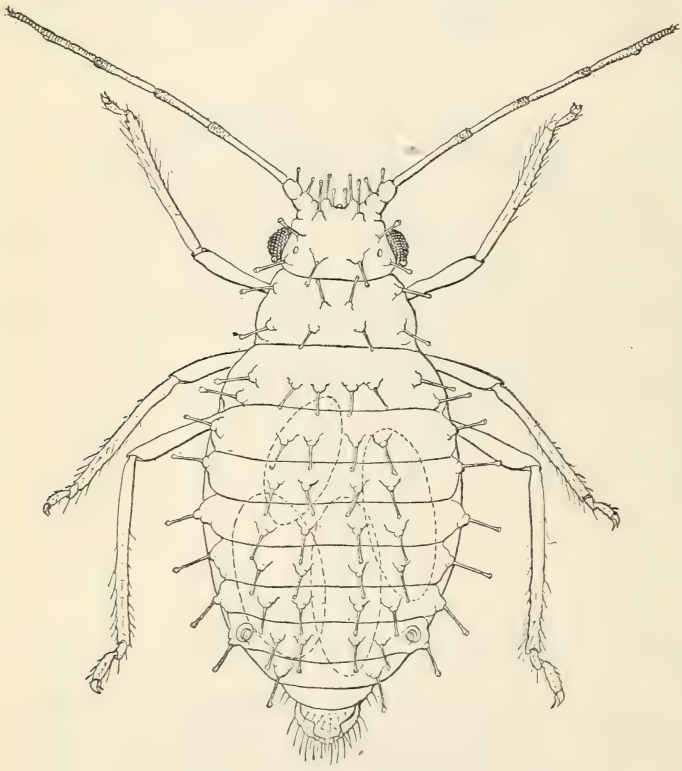


FIG. 16.—*Monellia caryella:* Oviparous female. (Original.)

an apical black ring on joints III to VI, inclusive; joints I, II, and filament dusky; joint III longest; joints IV and V subequal and each about four-fifths as long as joint III; filament a little shorter than VI; VI about four-fifths as long as V. Eyes crimson. Legs pale yellow; tarsi dusky. Hind tibiæ slightly thickened. Cornicles very small, pale. Cauda pale, globular, beset with a fringe of weak hairs, not as long as the hind tarsi. Thorax and abdomen with six longitudinal rows of capitate bristles, each surmounting a pale tubercle. Penultimate segment of the abdomen encircled near its posterior margin with a fringe of weak hairs. Eight capitate spines on the

head and six on the prothorax. Tibiæ armed with a row of short bristles on their inner margins. Beak pale, the extreme tip dusky, extending a little beyond the anterior coxæ. The young oviparous female is entirely pale yellow and can be distinguished from the young viviparous female only by its more eliptical shape, that of the latter being more oval. Measurements: Length of body, 1.89 mm.; width of body, 0.92 mm.; antenna, joint I, 0.075 mm.; joint II, 0.042 mm.; joint III, 0.312 mm. joint IV, 0.203 mm.; joint V, 0.218 mm.; joint VI, 0.167 mm.; filament, 0.108 mm. cauda, 0.080 mm.; cornicles, 0.009 mm.

Described from numerous specimens, Walnut Creek, Cal., October, 1912.

WINGED MALE (FIGS. 17; 18, *b*).

General color pale green or greenish yellow. Head and prothorax olive-green. Frontal margin of head and frontal margin of prothorax, black. Prothorax with two

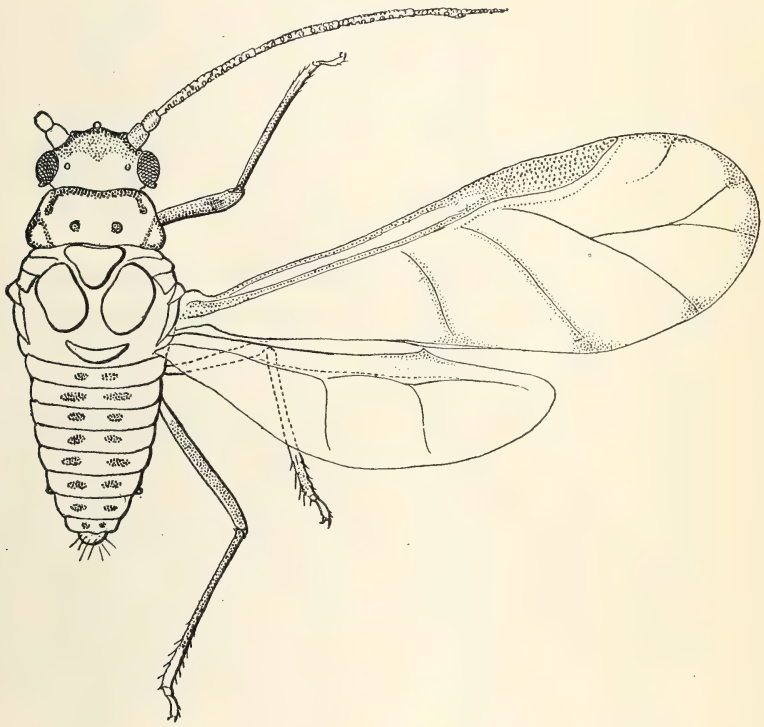


FIG. 17.—*Monellia caryella:* Winged male. (Original.)

bluntly rounded dusky tubercles on the dorsum. Dorsum of head and thorax with indefinite dusky markings. Eyes red. Antennæ dark olive-green, about three-fourths of the body in length; joint VI longer than its filament. Sensoria as follows: III, about 21: IV, 7 to 9; V, 6 to 10; VI, 2 to 4 (besides the usual apical). Wings of moderate size; insertions and subcosta greenish-yellow; stigma light brown, with a paler central area; discoidals 1 and 2 thicker than the other veins and with a narrow smoky border; stigmatic vein obsolete except for its apical third; veins brown. Legs pale greenish-yellow; coxæ, trochanters, apical five-sixths of femora, and basal four-fifths of tibiæ black; tarsi gray. Thoracic lobes and scutellum black. Under the wings

FIG. 18.—*a*, *Monellia caryæ*, antenna of male; *b*, *Monellia caryella*, two views of right antenna of male. (Original.)

occurs a large black spot on the pleuræ. Abdomen unarmed, pale green or greenish yellow; segments 1 to 8, inclusive, with two dusky brown oval spots on each. Cornicles pale, concolorous with the body, very small, considerably broader than long. Cauda concolorous with the abdomen, globular. Abdomen about as long as head and thorax combined, not wider than the thorax. Beak pale, barely reaching second coxæ. Sternum and underside of the eighth abdominal segment black.

Measurements: Length of body, 1.57 mm.; width of body, 0.62 mm.; expanse of wings, 4.62 mm.; antenna, joint I, 0.080 mm.; joint II, 0.041 mm.; joint III, 0.412 mm.; joint IV, 0.317 mm.; joint V, 0.260 mm.; joint VI, 0.175 mm.; filament, 0.108 mm.; cauda, 0.067 mm.; cornicles, 0.009 mm.

Described from three specimens, Walnut Creek, Cal., 1912 and 1913.

MONELLIA CALIFORNICA Essig.

Monellia californicus Essig, Pomona Jour. Ent., v. 4, no. 3, p. 767, Nov., 1912.

In southern California feeding on the underside of the leaves of the California black walnut (*Juglans californica*) there has recently been found a plant-louse closely allied to *Monellia caryæ* and *M. caryella*. The writer has never seen this aphis in nature, but has received specimens from Mr. Essig, who described it.

KEY TO THE SPECIES OF MONELLIA KNOWN TO OCCUR IN CALIFORNIA.

The following key will serve to distinguish the four species of walnut aphides occurring in California.

KEY TO THE SPECIES OF APHIDIDÆ KNOWN TO OCCUR ON WALNUT IN CALIFORNIA.

A. Cornicles quite evident, about as wide as long.
Chromaphis juglandicola Kalt.

AA. Cornicles barely perceptible, considerably wider than long.

B. Tibiæ of winged viviparous female entirely dusky.
Monellia californica Essig.

BB. Tibiæ of winged viviparous female for the most part pale.

C. Filament of joint VI longer than joint VI; oviparous female with four longitudinal rows of capitate hairs.... *Monellia caryæ* Monell.

CC. Filament of joint VI shorter than joint VI; oviparous female with six longitudinal rows of capitate hairs..... *Monellia caryella* Fitch.

NATURAL CONTROL OF WALNUT APHIDES.

INTERNAL PARASITES.

In July, 1912, a small chalcidid wasp was observed ovipositing in a pupa of *Monellia caryæ*. This is the only record of parasitism or attempted parasitism observed during two seasons, so there is good reason to believe that these aphides are practically immune from the attacks of internal parasites.

FUNGOUS DISEASES.

Although occasionally a plant-louse may be noticed here and there killed by fungus, only a single instance of the destruction of a colony by this agency came under the writer's notice. This occurred on May 20, 1911, following a rainstorm, and all the plant-lice on a few leaves were destroyed. The disease did not spread far, some cause or other checking the fungus shortly after its appearance.

PREDACEOUS ENEMIES.

Predaceous enemies are of prime importance in the control of plant-lice on walnuts and where the aphides occur in any numbers may always be found preying on them from June to September. Unfortunately they do not make their appearance on the walnuts until their prey has had time to do much damage to young nuts and to become abundant enough to cause collective injury to the tree. Should these predaceous forms appear in early spring they would quickly wipe out the few plant-lice present at that time and consequently their progeny would starve to death. As injury is thus done to the nuts and to the vitality of the tree before the advent of natural enemies, artificial measures must be practiced in order to insure healthy trees and perfect nut crops.

The predaceous enemies of walnut plant-lice include syrphus-fly larvæ, agromyzid larvæ, chrysopid and hemerobid larvæ, coccinellid beetles and their larvæ, *Camptobrochis brevis* Uhler (Heteroptera) and its larva, and various spiders.

Spiders.

The commonest spider predaceous on walnut plant lice is *Theridium placens* Keyserling. This spider may be found on the trees during the months of August and September and has a habit of curling around itself the edge of the leaf under the protection of which to deposit its egg sac. This species was determined by Mr. Nathan Banks, of the Bureau of Entomology, who says of it "* * * a species found on the Pacific coast. They do not choose their food, but from location of web are apt to get many plant lice." This and other spiders are of comparatively small economic importance in the control of aphides.

Camptobrochis brevis Uhler.

Camptobrochis brevis Uhler, which was determined by Mr. Otto Heidemann, of the Bureau of Entomology, is a small black capsid, measuring in the adult stage 4.2 by 1.9 mm. Its larva is white, with conspicuous black markings. Both immature and mature individuals were observed actively and abundantly attacking plant lice during August, 1912. They do not occur in numbers earlier in the year and disappear in September. Thus their beneficial work is limited.

Leucopis sp.

A fly of the family Agromyzidæ, *Leucopis* sp., in its larval state preys upon walnut plant lice from June to August. The small yellow maggots superficially resemble syrphid larvæ. They are never very abundant and are not a great factor in the control of the "lice." The life cycle in summer is completed in 24 days or less and there are several broods in California.

Chrysopid or Lacewing Flies.

Of scarcely less importance economically than the ladybird beetles and syrphid maggots are the active reddish-brown larvæ of the "lacewings." *Chrysopa majescula* Banks and *C. californica* Coq. are two species of economic importance in California. Table X shows the predatory activities of two larvæ of the latter species in the fall of 1912. The aphides consumed by these larvæ were of all sizes and averaged about 1.5 by 0.5 mm.

Table X.—*Chrysopa californica: Predatory activities on walnut plant lice, Walnut Creek, Cal., 1912.*

Larva No.	Date of—		Number "lice" eaten to molt 1.	Date of molt 2.	Number "lice" eaten, molt 1 to molt 2.	Date of spinning cocoon.	Number "lice" eaten from molt 2 to pupation.	Total "lice" eaten.	Number days feeding.
	Hatching.	Molt 1.							
1	Sept. 18	Sept. 22	11	Sept. 27	70	Oct. 8	265	346	20
2	18	21	22	26	57	7	300	379	19

Larva No. 1 ate on the average 17.3 "lice" per day, while larva No. 2 consumed 19.9 "lice" per day. The lacewing larvæ appear in numbers toward the end of June and may be found until the end of October. There are probably at least three broods, the last one wintering in the cocoon, which is white, short oval, with a central brown annulation, and is spun among the leaves or under a piece of bark. The closely allied but smaller hemerobiid larvæ also attack walnut plant lice.

Syrphid Larvæ.

Next to the ladybird beetles the larvæ of flies of the family Syrphidæ are of greatest importance in the natural control of walnut aphides. The author has reared the following species of Syrphidæ from larvæ collected while they were feeding on walnut aphides: *Catabomba pyrastri* Linnaeus (1911–12); *Sphærophoria melanosa* Williston (Aug. 24, 1912); *Sphærophoria sulphuripes* Thomson (Oct. 15, 1911); *Allograpta obliqua* Say (Aug. 6, 1912); *Eupeodes volucris* Osten Sacken (July, 1911). *Syrphus opinator* Osten Sacken, and probably other members of this genus, prey on the aphides. *Catabomba pyrastri* is the most abundant as well as the largest of these flies. Its aphidophagous capacity is almost double that of any of the other species enumerated above. Table XI indicates the predatory activities of two larvæ of the last brood of this fly.

Table XI.—*Catabomba pyrastri: Predatory activities on walnut plant lice, Santa Jose, Cal., 1912.*

Date.	Number of "lice" eaten by—		Date.	Number of "lice" eaten by—		Date.	Number of "lice" eaten by—	
	Larva No. 1.	Larva No. 2.		Larva No. 1.	Larva No. 2.		Larva No. 1.	Larva No. 2.
Aug. 29	[1]	[1]	Sept. 9	53	59	Sept. 18	92	107
30	4	4	10	65	85	19	50	104
31	15	15	11	76	62	20	36	10
Sept. 2	20	15	12	17	20	21	35	[2] 13
3	12	17	13	70	83	22	[2] 14	.....
4	11	17	14	62	77			
5	11	18	15	84	63	Total	959	1,035
6	23	36	16	74	83			
8	68	46	17	71	105			

[1] Hatched on this date. [2] Pupated on this date.

The "lice" consumed were of a similar average size to those eaten by the chrysopid larvæ (Table X). The larva of *Catabomba pyrastri* is pale green, with three longitudinal white stripes the whole length of the body, and when fully extended exceeds half an inch in length. The anterior segments of the body are retractile, giving it a sluglike appearance. If food is plentiful the larva moves but little, although it is capable of rapid crawling over the foliage if food is scarce. A parasite, *Bassus* sp., preys upon it, often destroying as much as two-thirds

of a brood and thus reducing its economic value. The maggot of the fly pupates commonly among fallen leaves or rubbish at the base of the tree, forming a light brown puparium (sometimes dark purplish-brown, in which case the specimen is parasitized), with a paler median longitudinal stripe. The adult fly is a large, shining black form, with three interrupted, pale-yellow, arcuate cross-bands (rarely wanting), and is 12 mm. long. Syrphid larvæ may be found preying upon walnut plant lice from May to November, although they are quite scarce in the two extreme months.

Ladybird Beetles (Family Coccinellidæ).

Ladybird beetles are the principal enemies of aphides affecting walnuts. The author has observed the following species feeding on these aphides: (1) *Olla abdominalis* Say; (2) *Adalia melanopleura* Le Conte; (3) *Coccinella juliana* Mulsant; (4) *Adalia humeralis* Say; (5) *Hippodamia convergens* Guerin; (6) *Hippodamia ambigua* Le Conte; (7) *Coccinella californica* Mannerheim; (8) *Adalia bipunctata* Linnæus; (9) *Chilocorus orbus* Casey. Nos. 1 to 8 in both adult and larval stages feed on the plant lice on the leaves, while the adults of the *Chilocorus* occasionally attack the winter eggs on the limbs. Nos. 1 to 4 are the most persistent enemies of the aphides, the others only appearing spasmodically on the trees. The Hippodamia group of lady birds seems to prefer such intensely gregarious plant lice as the plum louse (*Hyalopterus arundinis* Fabricius) or the bean aphis (*Aphis rumicis* Linnæus) and pay much less attention to the more sporadic varieties such as the aphides on walnuts.

Table XII indicates the predatory activities of five larvæ of *Olla abdominalis* (the ashy-gray ladybird.)

Table XII.—*Olla abdominalis: Predatory activities on walnut plant lice, San Jose, Cal., 1912.*

Larva No.	Date of hatching.	Date of molt 1.	Number of "lice" eaten to molt 1.	Date of molt 2.	Number of "lice" eaten, molts 1 and 2.	Date of molt 3.	Number of "lice" eaten, molts 2 to 3.	Date of pupation.	Total "lice" eaten.	Date of adult emergence.
1	Aug. 27	Aug. 30	29	Sept. 2	36	Sept. 5	91	Sept. 13	477	Sept. 22
2	31	Sept. 5	38	9	30	12	45	19	417	25
3	31	5	24	9	33	12	50	18	237	25
4	31	5	35	9	27	12	59	18	234	25
5	31	5	39	9	31	12	53	18	320	25

In all, 1,685 "lice" were eaten in 90 days, or 18.7 "lice" per day per larva. The "lice" were of similar average size to those consumed by the lacewing larvæ (Table X). It was noticed that before the first molt the ladybird larvæ would eat only very small aphides.

The following is a brief account of the stages of the ashy-gray ladybird (*Olla abdominalis*) (Pl. III). *The egg:* Yellow, later becoming

orange-colored; cylindrical, long oval, slightly tapering to either end, four times as long as broad; deposited in compact masses of from 5 to 25 on the leaf, usually on the underside, and with their long axis at right angles to the leaf surface; size, 1.3 by 0.35 mm. *The larva:* All black at hatching, later with pale markings, becoming more distinct after each successive molt. After the third molt the general color is dark purplish-black, with a median line of pale brick-red spots on the thorax and abdomen and also two lateral rows of similar spots. On segments 1 and 4 of the abdomen occur also two pale spots, one on either side of the median brick-colored spot and midway between it and the corresponding lateral spot. The full-grown larva has a length of 8 millimeters. *The pupa:* General color white, wing pads sienna brown. A large number of black spots and dashes are present but the prevailing color is white. Average size, 4 by 3.3 mm. *The adult:* Hemispherical, ashy-gray, with black markings, the elytra sometimes diffused with dull reddish blotches; head black, with central portion white or light gray; thorax (pronotum) black, with gray margins; elytra ashy-gray, with eight black spots on each elytron; legs yellow; abdomen reddish-yellow; average size, 5.2 by 4.2 mm. The adults of this species, if confined without food, will devour one another.

Table XIII indicates the predatory activities of two larvæ of *Adalia melanopleura* on walnut plant lice.

TABLE XIII.—*Adalia melanopleura: Predatory activities on walnut plant lice, Walnut Creek, Cal., 1912.*

Larva No.	Date of hatching.	Date of molt 1.	Number "lice" eaten to molt 1.	Date of molt 2.	Number "lice" eaten, molts 1 to 2.	Date of molt 3.	Number "lice" eaten, molts 2 to 3.	Date of pupation.	Total "lice" eaten.	Date of adult emergence.
1	Sept. 17	Sept. 20	41	Sept. 24	38	Sept. 26	30	Sept. 30	181	Oct. 12
2	17	19	35	22	34	25	33	30	194	12

In all, 375 plant lice were eaten in 26 days, or 14.4 per day per larva. The feeding period of both larvæ was 13 days as contrasted with an average of practically 18 days for the larvæ of the ashy-gray lady-bird. *Adalia melanopleura* is considerably smaller than that species, its larva consuming in a period of 13 days half as many plant lice as the larva of the larger species will devour in 18 days. This larger species will consume 70 larvæ in a single day while the maggot of the large syrphid fly (*Catabomba pyrastri*) will dispose of over 100 and during the 23 days or so of its existence will devour over 1,000, or about 43.5 lice per day. However, in contrasting the two groups of predaceous insects—Syrphidæ and Coccinellidæ—it must be remembered that the former are aphidophagous only in the larval state

while both the adults and larvæ of ladybirds feed on plant lice. Mr. E. K. Carnes,[1] experimenting in the State Insectary at Sacramento, Cal., found that 20 adult beetles of *Hippodamia convergens* averaged 21.8 aphides per day and that the larvæ of this species each consumed from 250 to 300 plant lice during their larval existence. He found that adult females would deposit eggs for from a month to six weeks, laying on the average 15 eggs per day and feeding on the plant lice all the time. Essig[2] states that in the walnut orchards of Ventura County, Cal., *Olla abdominalis*, the ashy-gray ladybird, is by far the most beneficial insect in the natural control of the European walnut aphis (*Chromaphis juglandicola*).

ARTIFICIAL CONTROL OF WALNUT APHIDES.

The writer has been unable, save in one instance,[3] to find any published account of artificial control tried or adopted for walnut plant-lice. Until the year 1910 no such work seems to have been performed along this line.[4] In August of that year Mr. P. R. Jones, late of the Bureau of Entomology, carried out a series of laboratory experiments with a view to determining the efficiency of various washes against these aphides. A small hand pump was fitted with an Eddy-chamber nozzle and the applications made at a medium high pressure. Care was taken that not enough pressure was exerted to kill any of the "lice" by the force of the spray alone. Examinations were made 10 minutes after the applications. From these experiments the following results were obtained:

Commercial tobacco extract No. 2, containing 40 per cent nicotine, at strengths of 1–1,040 to 1–2,048, effective; dilutions weaker than 1–2,048, not effective.

Commercial tobacco extract No. 1 containing about 4 per cent of nicotine at strength of 1–60, effective; dilutions weaker than 1–60, not effective (1–80 partially effective).

Commercial tobacco extract No. 1, at strengths varying from 1–60 to 1–200, combined with a 3 per cent distillate-oil emulsion, effective.

Commercial tobacco extract No. 2 at strengths varying from 1–1,000 to 1–2,650 combined with a 3 per cent distillate-oil emulsion, effective.

Commercial tobacco extract No. 1 at strengths varying from 1–60 to 1–200 combined with a 2 per cent distillate-oil emulsion, effective.

Commercial tobacco extract No. 2 at strengths varying from 1–1,000 to 1–2,620 combined with a 2 per cent distillate-oil emulsion, effective.

Distillate-oil emulsion at 2, 3, and 4 per cent strengths, effective.

Commercial lime-sulphur, 1–50, combined with commercial tobacco extract No. 1, 1–100, effective.

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[1] Sept., 1912. Carnes, E. K. Insectary Division Reports for the months of June and July, 1912. Mo. Bul. Cal. State Hort. Com., v. 1, no. 10, p. 820–828.

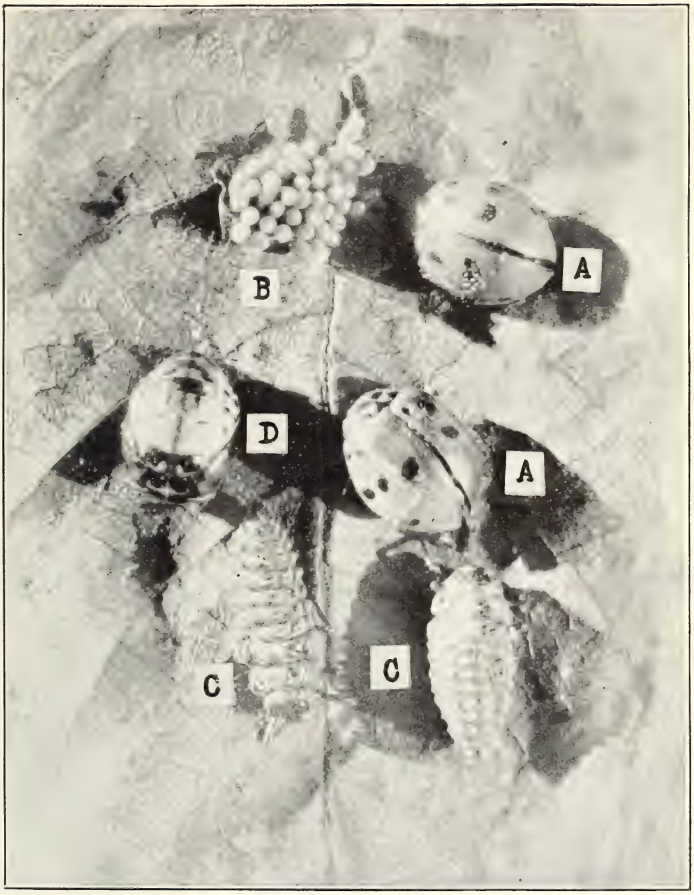
Some experiments with the common ladybird (*Hippodamia convergens*), p. 821–826.

[2] Apr., 1912. Essig, E. O. The walnut plant louse (*Chromaphis juglandicola* [Kalt] Walker). Mo. Bul. Cal. State Com. Hort., v. 1, no. 5, p. 190–194, figs. 72–73.

Control, p. 192.

[3] Cf. Biennial Crop Pest and Hort. Report 1911–1912, Oregon Agr. Coll. Exp. Sta. Jan. 10, 1913, p. 165. "Blackleaf 40" and kerosene emulsion 10 per cent recommended.

[4] Since going to press control experiments undertaken in the spring of 1913 in Southern California by the University of California have been published in Circular 107 of the Agricultural Experiment Station of the University of California.



THE ASHY-GRAY LADYBIRD (OLLA ABDOMINALIS).
[A, adult; B, eggs; C, larva; D, pupa. (After Essig.)]

FIG. 1.—TREE OF THE ROYAL HYBRID WALNUT IN GROVE OF MR. F. LEIB, SAN JOSE, CAL.

FIG. 2.—GENERAL VIEW OF WALNUT GROVE OF MR. F. LEIB, SAN JOSE, CAL.

Commercial lime-sulphur, 1–50, combined with commercial tobacco extract No. 1, 1–200, effective.

Commercial lime sulphur, 1–70, combined with commercial tobacco extract No. 2, 1–1,000, effective.

Commercial lime-sulphur 1–45, combined with commercial tobacco extract No. 2, 1–2,000, effective.

It is noticeable that the weaker solutions of tobacco extracts were not effective alone, but when combined with distillate-oil emulsion or lime-sulphur proved quite satisfactory. Possibly the most successful result was obtained with distillate-oil emulsion of only 2 per cent. Field experiments failed, however, to justify the use of this wash alone, for it proved to lack the killing power found in the tobacco-extract sprays. The emulsion serves, however, as a very good "spreader" for the nicotine killing agent, since it serves to distribute the spray over the leaf surface. Commercial tobacco extract No. 2 proved to have greater insecticidal value than commercial tobacco extract No. 1, judging by the corresponding strengths of the two sprays; and therefore in the field only the former was used. Foliage tests on an Eastern black walnut tree were made of all the washes used in the laboratory experiments, and in no case was any burning observed to result. This type of walnut seems more susceptible to burning injury than does the European or so-called "Persian" walnut.

FIELD EXPERIMENTS.

SPRING AND SUMMER TREATMENT.

Experiment No. 1.—Lime-sulphur (commercial 1–50) combined with commercial tobacco extract No. 2 (1–1,500). Orchard of Mr. I. Du Bois, San Jose, Cal. Two large European walnut trees badly infested with aphides were sprayed July 1, 1911, under an even pressure of 170 pounds. A count made on the following day showed that 95 per cent of the aphides had been destroyed by the wash.

Experiment No. 2.—Three per cent standard distillate-oil emulsion combined with commercial tobacco extract No. 2 (1–2,000). A large, badly infested European walnut tree in the yard of the experiment station at San Jose was treated, July 3, 1911, with this spray at an even pressure of 170 pounds. A count made July 5 showed that over 95 per cent of the aphides had been killed.

Experiment No. 3.—Commercial tobacco extract No. 2 (1–1,500). Orchard of Mr. F. Leib, near San Jose, Cal. (Pl. IV, figs. 1, 2). A block of 10 walnut trees badly infested was sprayed, May 21, 1912, under a pressure fluctuating from 60 to 140 pounds. A count made two days later showed that not over 40 per cent of the "lice" were destroyed.

Experiment No. 4.—Commercial tobacco extract No. 2 (1–1,500) combined with 2 per cent homemade distillate-oil emulsion. Orchard of Mr. F. Leib, near San Jose, Cal. A block of 10 badly infested walnut trees was sprayed, May 21, 1912, under pressure similar to that of experiment No. 3. A count made two days later showed that 98 per cent of the insects had succumbed. Some oil burning appeared on the foliage and nuts owing to insufficient agitation in the preparation of the emulsion and consequent freeing of oil.

Experiments Nos. 3 and 4 were made to determine whether the tobacco extract alone would prove effective in the field. Results indicate that a weak solution of oil emulsion is necessary to act as a "spreader" for the tobacco.

Experiment No. 5.—Distillate-oil emulsion, 2 per cent. Orchard of Mr. F. Leib, near San Jose, Cal. A block of six badly infested walnut trees was sprayed under 110 pounds pressure, July 31, 1912. A count made on August 6 showed that 74 per cent of the "lice" had been destroyed.

Experiment No. 6.—Distillate-oil emulsion, 2 per cent, combined with commercial tobacco extract No. 2 (1–2,000). Orchard of Mr. F. Leib, near San Jose, Cal. (Pl. IV, figs. 1, 2). Six walnut trees, badly infested, were sprayed under a pressure of 110 pounds. A count, made August 6, showed that 85 per cent of the "lice" had been killed by the spray.

Experiment No. 7.—Whale-oil soap, 1 pound; water, 5 gallons. Orchard of Mr. E. I. Hutchinson, Concord, Cal. A block of 12 moderately infested European walnut trees was sprayed under 150 pounds pressure, May 10, 1913. A count made two days later showed that out of 473 "lice" counted, 263, or 55.6 per cent, had been destroyed. A thorough drenching had been applied and the trees were in full leaf. It was noticed that the great majority of the "lice" that escaped were situated close to the base of the midrib. In this position they were partly protected by the projecting rib, and it is to be supposed that the wash lacked the pressure necessary to reach these individuals.

All the foregoing experiments were undertaken on trees on which the foliage was fully developed. It was noticeable that on thickly foliated trees the percentage of plant lice killed was the smallest, while on thinly foliated trees the greatest mortality resulted. Much of the leaf surface on thickly foliated trees is almost inaccessible to spray.

A comparison of the results of the foregoing tests favors distillate-oil emulsion and tobacco. The most desirable combination for spring and summer spraying is a 2 per cent distillate-oil emulsion, commercial or homemade, combined with commercial tobacco extract No. 2, 1 to 1,500. High pressure (150 pounds or over) is desirable, although not absolutely necessary unless the spraying be done before the walnut leaflets have flattened out in spring.

In timing the application for the aphides on the leaves it is desirable to spray as early as possible in order to reduce the amount of leaf surface to be covered by the wash and to destroy the plant lice before they attack the nuts. On the other hand it will be found very hard to destroy the plant lice before the leaflets flatten out, for the young leaflets are pressed against one another in a manner that affords very good protection to the insects from a spray. Moreover at this period all the stem-mother plant lice will not have hatched from the winter eggs. The time most preferable for the application is just as soon as the growing leaflets shall have flattened out and before they have attained their full size. At this time the "lice" have all hatched and are all exposed on the underside of the leaves. Should an oil spray be applied care should be taken that there is no free oil in the emulsion, as the young nuts are susceptible to burning. No stronger than a 2 per cent distillate-oil emulsion should be used for this early application. The spray should be directed to the underside of the leaves, and angle nozzles used. A round nozzle is to be pre-

ferred to one of the Clipper type, as the former will diffuse the spray better over the leaf surface. Such a driving-spray nozzle as that devised by the Massachusetts Agricultural College is desirable for spraying trees of large size. If there are unsprayed walnut trees in the vicinity it may be necessary to make a second application some two or three weeks later, as plant lice are apt to have migrated from these to the sprayed trees.

On account of the extended period over which the sexual forms are produced, fall spraying for these forms, unless repeated again and again, will be of little value.

It should be borne in mind that the number of "lice" hatching in the spring from the winter eggs varies considerably year by year in a given locality or orchard and also that the hatching time of these "lice" is regulated by the sap flow in that particular tree upon which the eggs happened to be placed. The hatching of the winter eggs is not regulated by temperature conditions. Hence the stage in the seasonal development of the aphidids corresponds to the stage in development of that particular tree on which the stem-mother lice were produced, leaving out of consideration the possibility of migrants arriving from other trees. This point is of importance when it is considered that the different varieties of cultivated walnuts put out their leaves and produce their nuts at different times and that these functions are performed by individual varieties at different times dependent on locality and seasonal meteorological conditions.

Table XIV summarizes the control experiments made for spring and summer treatment.

TABLE XIV.—*Summary of spring and summer spraying experiments against walnut aphides, San Jose and Walnut Creek, Cal., 1911, 1912, and 1913.*

Character of spray.	Date of application.	Number trees sprayed.	Result of spray; per cent of plant lice killed.	Cost per diluted gallon.
Commercial lime-sulphur, 1–50 and commercial tobacco extract No. 2 (1–1,500)	July 1,1911	2	95	$0.012
3 per cent distillate-oil emulsion (homemade) and commercial tobacco extract No. 2 (1–2,000)	July 3,1911	1	95	.0088
Commercial tobacco extract No. 2 (1–1,500)	May 21,1912	10	40	.008
2 per cent distillate-oil emulsion (homemade) and commercial tobacco extract No. 2 (1–1,500)	do	10	98	.0098
2 per cent distillate-oil emulsion (commercial)	July 31,1912	6	74	.0067
2 per cent distillate-oil emulsion (commercial) and commercial tobacco extract No. 2 (1–2,000)	do	6	85	.0127
Whale-oil soap (homemade), 1 pound to 5 gallons water	May 10,1913	12	55.6	.004

WINTER TREATMENT.

Experiment No. 1.—Crude-oil emulsion, 12 per cent (crude oil, 27° Baumé). Orchard of Mr. George Whitman, Concord, Cal. A block of 31 European walnut trees of moderate size were sprayed February 25, 1913, under a pressure of from 150 to 175 pounds. Three gallons of spray were applied to each tree and "Friend" nozzles used. The trees were well drenched. Examination made April 5, 1913, showed that trees were starting to leaf. Most of the leaves were as yet tightly closed, but the basal leaves of many

shoots were opened. A general survey of the sprayed block and of a check unsprayed block indicated equal infestation by young stem mothers. Plant lice were not all hatched. An examination made April 15, 1913, showed that trees were well out in leaf. All stem mothers had hatched. A general survey of sprayed and unsprayed trees showed no apparent difference in infestation. A count of 28 leaf clusters selected at random from the sprayed trees yielded 21 stem mothers, while a similar count of the same number of leaf clusters from unsprayed trees yielded 29 stem mothers. It may be inferred from this experiment that the crude-oil emulsion destroyed few, if any, of the winter eggs.

Experiment No. 2.—Commercial lime-sulphur, 1–10. (Concentrated solution, 33° Baumé.) Orchard of Mr. George Whitman, Concord, Cal. A block of four large trees of the European walnut were sprayed March 5, 1913, under a pressure of 100 pounds. About 14 gallons of spray were applied to each tree and "Friend" angle nozzles used. Eggs were abundant on both sprayed and check trees. The leaf buds on these trees began to open April 1, 1913. Examination was made April 15, 1913. Trees were then well out in leaf. The stem mothers were all hatched. The lime had no effect in retarding leafing. A count of 20 leaf clusters taken at random on the sprayed block yielded no plant lice, while a similar count of the same number of leaves on the check trees yielded 27 stem mothers. Further examination showed that on the sprayed trees no plant lice could be found, while on the check trees nearly every leaf cluster had one or more of the insects.

A subsidiary experiment was undertaken on two young California black walnut trees, both infested with eggs. One of these trees was treated with commercial lime-sulphur, 1–9 (concentrated solution 33° Baumé), and the other left as a check. On the sprayed tree no eggs hatched and when examined on April 17, 1913, the eggs were shrunken and distorted, the embryos having been destroyed within the eggshell. The eggs on the check tree hatched normally about the end of March.

Experiment No. 3.—Crude-oil emulsion, lime-sulphur, and "Yel-ros." Vrooman orchard, Santa Rosa, Cal. Four plats were sprayed, April 9–11, 1913, with a power outfit at high pressure, as follows: Plat 1, 40 trees, crude oil (22° Baumé) emulsion, 8 per cent; plat 2, 40 trees, lime-sulphur, 1 to 8; plat 3, "Yel-ros," 1 to 25, 16 trees; plat 4, "Yel-ros," 1 to 40, 24 trees. These applications were made on late Franquette walnuts, dormant at the time of spraying. The orchard was well infested with the winter eggs of the plant lice. An examination, May 27, 1913, showed that the trees were well out in leaf. Stem mother plant lice were mostly about two-thirds grown. Counts of 80 leaves (about 480 leaflets) taken at random from each of the four plats and from a check unsprayed plat resulted as follows:

TABLE XV.—*Winter spraying experiment No. 3 against walnut aphides, Vrooman orchard, Santa Rosa, Cal., 1913.*

Plat.	Number of "lice" on 80 leaves.	Per cent of number on check.
Crude-oil emulsion, 8 per cent	11	10.6
Lime-sulphur, 1 to 8	2	1.9
"Yel-ros," 1 to 25	14	13.4
"Yel-ros," 1 to 40	97	93.2
Check—unsprayed	104	100.0

The best results, therefore, were obtained by the lime-sulphur wash. The greater efficiency of the 8 per cent crude-oil emulsion over the 12 per cent crude oil used in experiment No. 1 is probably due to the heavier grade of oil (22° Baumé) used in the 8 per cent experiment. The heavier oil remains longer on the trees and coats the eggs of the aphides more satisfactorily than the oil of lighter grade. As may be seen from Table XVI both the 8 per cent crude-oil emulsion and "Yel-ros," 1 to 25, gave good results, but "Yel-ros," 1 to 40, was quite ineffective. Table XVI is a summary of experiments against the winter eggs:

TABLE XVI.—*Summary of experiments on the winter eggs, Walnut Creek and Santa Rosa, Cal., 1913.*

Character of spray.	Date of application.	Number of trees sprayed.	Date of examination.	Plant lice present (check—100).	Cost per diluted gallon.
				Per cent.	
Crude-oil (27° Baumé) emulsion, 12 per cent	Feb. 25	31	Apr. 5, 15	72.4	$0.01
Commercial lime-sulphur, 1 to 10	Mar. 5	4	do	.0	.02
Crude-oil (22° Baumé) emulsion, 8 per cent	Apr. 9–11	40	May 27	10.6	.0073
Commercial lime-sulphur, 1 to 8	do	40	do	1.9	.025
"Yel-ros," 1 to 25	do	16	do	13.4	.028
"Yel-ros," 1 to 40	do	24	do	93.2	.0175

It is in a measure unfortunate that the homemade 1–2–1 lime-sulphur spray was not tried. This is considerably cheaper than the commercial article, but there is no reason to suppose that the winter formula of the homemade lime-sulphur would not prove quite effective judging by the results obtained with commercial lime-sulphur.

In recommending winter sprays for the plant lice infesting walnut trees the writer must accord the preference to lime-sulphur, 1–8 to 1–11, while good work may be expected from crude-oil emulsion, 8 to 12 per cent, using the heavier grades of oil (not lighter than 24° Baumé), and from "Yel-ros," 1–25. The oil emulsion (homemade) is the cheapest winter spray, although there is little difference between its cost and that of the homemade lime-sulphur wash, winter formula.

In applying the spray for the aphis eggs the wash should be directed so as to cover completely every part of the twigs and limbs. Late spraying, i. e., making the application just before the buds are beginning to swell, is preferable to spraying earlier, especially if crude-oil emulsion is used, as the oil does its best work soon after it is applied and the plant lice at hatching time are more easily destroyed by it.

In concluding the section on artificial control the author would like to express his thanks to Mr. Frank Leib, San Jose, Cal., and Messrs. George Whitman and E. I. Hutchinson, Concord, Cal., for their help and cooperation in the carrying out of field experiments on their orchards, and also to Balfour, Guthrie & Co., San Francisco, Cal., by whose courtesy the Santa Rosa experiments were made possible, they having made the spray applications under the author's supervision.

SUMMARY.

The life history of walnut aphides in California is briefly as follows: A week or so before the buds open on the trees in the spring the aphidids begin to hatch from the winter eggs. As soon as the young foliage appears the "lice" settle on it, and after feeding for a month or so become adults. These stem mothers are always winged and like plant lice of later generations are capable of migrating to other trees and orchards. As soon as they are fully developed they produce young parthenogenetically. These second-generation young become mature in three weeks and in turn produce young. The individuals of the third and subsequent generations of summer mature in about 16 days. On early-leafing varieties there are 10 or 11 viviparous generations in the year while on late varieties there are 8 or 9. The production of the sexual generation is prolonged over four months, these forms first appearing in July. After the sexes (comprised of the winged male and the wingless female) mate, the female repairs to the twigs and limbs of the tree, there to deposit her eggs. Winter is passed in the egg stage only.

In general the aphidids inhabit the underside of the leaves, but those of the second, third, and fourth generations often attack the nuts, sometimes seriously dwarfing them (see Pl. I, fig. 1). Occasionally the "lice" will be found on the upper surface of the leaf. When infestation on the leaves and nuts is severe the vitality of the infested tree is impaired. The aphidids excrete a sweet, gummy, transparent substance much sought after by ants, and in this thrives a black sooty fungus. This black fungus often covers the upper sides of the lower leaves and the upper part of the nuts, thereby interfering with the respiratory action of the plant tissues.

Walnut plant lice have many natural foes, all predatory. These serve to keep the aphidids in check but do not appear in sufficient numbers until after the "lice" have had time to injure the nuts. The most persistent of them is the ashy-gray ladybird beetle (*Olla abdominalis* Say).

Aphidids on walnuts can be controlled artificially with sprays. The winter spraying directed against the eggs is the easier to apply, and high trees can be reached by a winter wash with ease, whereas in the spring and summer so thick is the foliage that a thorough application is hard to accomplish satisfactorily. Furthermore, far less material is required when the trees are bare. Lime-sulphur and crude-oil emulsions are effective, especially the first named. The spray should be directed all over limbs and twigs so as to cover every part. If it is necessary to spray in spring or summer, a combination of 2 per cent distillate-oil emulsion and commercial tobacco extract No. 2 (1 to 1,500) will prove effective provided it be applied under a pressure of at least 150 pounds and the spray directed on the nuts and underside of the leaves.

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